METALLURGIA

THE BRITISH JOURNAL OF METALS

Vol. 52 No. 312 OCTOBER, 1955 Monthly: TWO SHILLINGS

METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

CONTENTS FOR OCTOBER, 1955 Vol. 52 No. 312

PUBLISHED MONTHLY BY

The Kennedy Press, Ltd.,
31, King Street West,
Manchester, 3.
Telephone : BLAckfriars 2084

London Office :

50, Temple Chambers,
Temple Avenue, E.C.4.
FLEet Street 8914

CONTRIBUTIONS

Readers are invited to submit articles for publication in the editorial pages: photographs and/or drawings suitable for reproduction are especially welcome. Contributions are paid for at the usual rates. We accept no responsibility in connection with submitted manuscript. All editorial communications should be addressed to The Editor, "Metallurgia," 31, King Street West, Manchester, 3.

SUBSCRIPTIONS

Subscription Rates throughout the World—24/- per annum, Post free.

ADVERTISING

Communications and enquiries should be addressed to the Advertisement Manager at Manchester.

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LABORATORY METHODS SUPPLEMENT

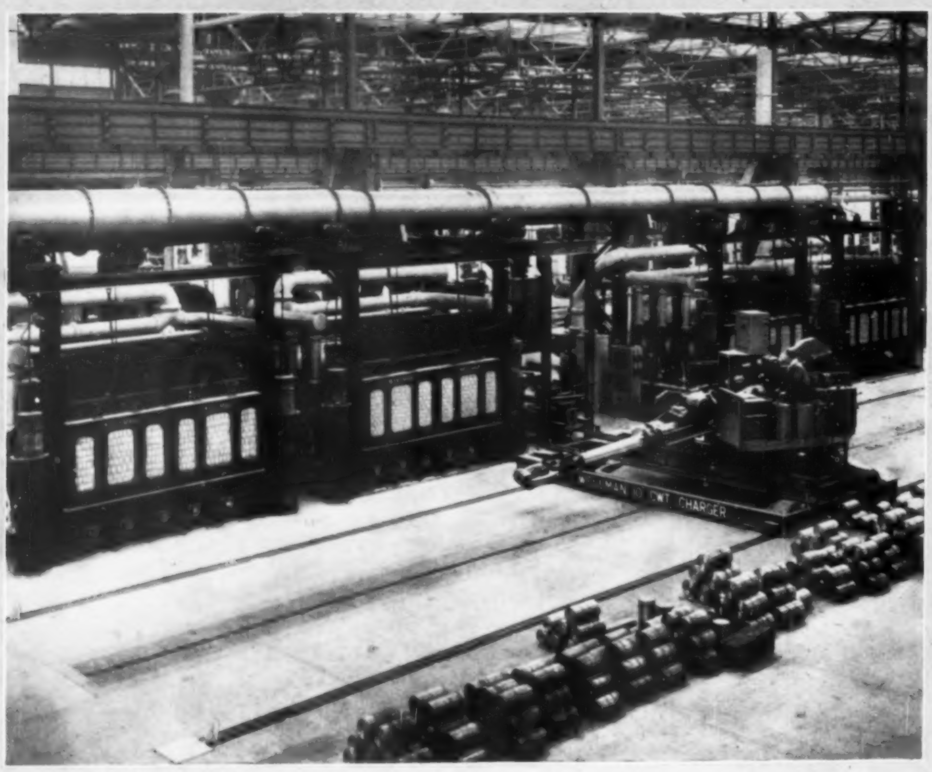
The articles in this Journal are indexed in THE INDUSTRIAL ARTS INDEX

WELLMAN

UNDERTAKE

COMPLETE INSTALLATIONS

FURNACES — MECHANICAL PLANT



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METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

OCTOBER, 1955 Vol. LII. No. 312

Efficiency and Enthusiasm

A STRIKING illustration of the changes which have taken place in the steel industry in the post-war years is given by the fact that output has risen by five-eighths, with an increase of no more than one-eighth in the labour force. This is, of course, only one result of the industry's modernisation and development programmes, but it is an indication of the improvement in efficiency which has been achieved. The task of management is to use the available factors of production—raw materials, fuel, equipment and labour—as economically as possible, the final criterion of success being the level of costs. This does not necessarily mean the reduction of the cost level for all the production factors, for, as is pointed out in an article in the September issue of the *Monthly Statistical Bulletin* of the British Iron and Steel Federation, it may be possible to secure larger output from a given furnace, thus economising in capital equipment, at the expense of an increased unit consumption of fuel; again, labour may often be saved by the use of additional equipment. In all such cases, the substitution will be economically justified if it results in a reduction of total costs per unit of output. The relative cost levels for the various production factors will vary from country to country, and even from district to district in the same country, so that the most economical set-up for one may not be the best for another. An instance of this is the influence of labour costs in the United States, which results in a tendency to drive furnaces hard, even at the expense of considerably higher fuel costs and greater wear and tear.

Although there are variations from district to district, some of the ways in which economies have been effected will serve to illustrate how efficiency has been improved. Perhaps the most important factor on the raw materials side has been the considerable extension in the use of the sintering process, which enables ore fires, pyrites residues, flue dust, and even old accumulations of slag to be converted into a product suitable for charging into the blast furnace. Again, in the tinplate trade, economy in the use of that expensive material, tin, has resulted from the increasing application of the electrolytic tinning process. Alloy steel producers, too, have saved critical alloying elements by recovery from scrap, by changes in alloy steel specifications, and by the substitution of one alloying element for another.

Fuel economy has been effected in a number of ways. On the blast furnace side, sintering and, indeed, all forms of ore preparation have reduced the total coke requirement per ton of iron by making more efficient use of the blast furnace gases. Taking the post-war period as a whole, the industry's coke consumption per ton of pig iron has been reduced from rather more than 22 cwt. to rather less than 20 cwt. The growth of the hot metal process has probably contributed more than any other factor to the saving of fuel in steelmaking, although the fuller utilisation of by-product gases—facilitated by vertical integration of processes—has no doubt helped. The two main factors tending to greater fuel efficiency in the finishing sections are improved mechanical design and continuous rolling processes which eliminate the need for reheating. In several sections of the industry, fuel is being saved by improved instrumentation and the automatic control of furnaces.

In a highly capitalised industry such as steel, where the equipment may, perhaps, cost as much as £10,000 for every worker employed, considerable efforts have been made to economise on plant costs by getting the maximum output from a given unit. In contrast with many industries where equipment is used for only one shift a day, five days a week, the steel industry's plant works 17 to 21 shifts a week. This has been achieved by the general adoption of the continuous working week—a good example of the excellent management-labour relations for which the industry is noted. Further increases in output have been obtained by the adoption of different fuels for firing, and there are signs that the use of oxygen to speed up refining processes will result in further improvement at the cost of little capital outlay: a tonnage oxygen plant is to be erected in Lincolnshire to serve the works in the Scunthorpe area. Planned maintenance has also played its part, not only by reducing the period during which plant is idle for maintenance purposes, but also by reducing the risk of breakdown, with consequent loss of output. In considering ways of achieving economy in capital expenditure, sight has not been lost of the possibility of dispensing with certain items of equipment, and work at present in progress on the development of the continuous casting process may eliminate the need for expensive cogging and billet mills and reduce the throw-up of scrap.

The last production factor to be considered is labour, and economy in this field in the steel industry has had the full support of the unions, whose leaders are as productivity conscious as any in the country. Since the war, the arrangements whereby the wages of skilled men included a tonnage element have been extended to cover the majority of workers in the industry, and this has no doubt contributed to the improved output per man. The main economy of labour—as well as materials and fuel—has, however, been achieved by large scale capital investment, which has enabled each man to handle larger tonnages than before.

Reference has been made to the excellent labour relations which have facilitated the trial of new techniques, but without the enthusiasm of the technologists responsible progress would not have been so rapid as it has. To anyone entering the steel industry from other fields, one of its most striking features is the readiness with which information is shared and visits are exchanged between one firm and another for the purpose of discussing mutual problems: the same attitude is also seen in relation to the publications and meetings of technical societies. Such an outlook may not be acceptable in other industries, but the steel industry as a whole undoubtedly benefits by it.

Forthcoming Meetings

1st November

Incorporated Plant Engineers, London Branch. "Corrosion and Fouling in Industry," by E. J. Bradbury. Royal Society of Arts, John Adam Street, London, W.C.2. 7 p.m.

Institute of Metals, Oxford Local Section. "Some Aspects of Bright Plating," by Dr. G. L. J. Bailey. Ballroom of the Cadena Cafe, Cornmarket Street, Oxford. 7 p.m.

Institution of Engineering Inspection, Coventry Branch. "Quality Castings in Light Alloys," by P. A. Broadbent. Room A5, Coventry Technical College. 7.30 p.m.

Institution of Engineers and Shipbuilders in Scotland. "Aluminium Tanker," by Dr. E. C. B. Corlett. 39, Elmbank Crescent, Glasgow. 7.30 p.m.

Institution of Production Engineers. "The Practical Application of Production Engineering Research," by Dr. D. F. Galloway. The Cleveland Scientific and Technical Institution, Middlesborough. 7 p.m.

Sheffield Metallurgical Association. "Strain-Ageing in Deep Drawing Mild Steels," by Dr. B. B. Hundy. B.I.S.R.A Laboratories, Hoyle Street, Sheffield, 3. 7 p.m.

2nd November

Institution of Production Engineers. "Powder Metallurgy," by G. R. Bell. The Ilford Club, 21a, Balfour Road, Ilford. 7.30 p.m.

Institution of Production Engineers. "The Shell Moulding Process," by D. N. Buttrey. The Campbell Hotel, Bridge Street, Peterborough. 7.30 p.m.

3rd November

Institute of Metals, Birmingham Local Section. "Radiation Damage in Metals," by Dr. W. M. Lomer. James Watt Memorial Institute, Great Charles Street, Birmingham. 6.30 p.m.

Institute of Metals, London Local Section. "The Rare Earths," by A. R. Powell. Royal School of Mines, South Kensington, London, S.W.7. 7 p.m.

Leeds Metallurgical Society. "Grain Boundaries," by Dr. D. McLean. Large Chemistry Lecture Theatre, The University, Leeds, 2. 7.15 p.m.

7th November

East Midlands Metallurgical Society. "Boron in Steel," by F. B. Pickering. Nottingham and District Technical College, Shakespeare Street, Nottingham. 7.30 p.m.

8th November

Institute of British Foundrymen, Slough Section. "Production of Moulds and Cores by the CO_2 Process," by A. Talbot. Lecture Theatre, High Duty Alloys, Ltd., Slough. 7.30 p.m.

Institute of Metals, South Wales Local Section. "The Effect of Trace Impurities on Iron," by Dr. N. P. Allen. Department of Metallurgy, University College, Singleton Park, Swansea. 6.45 p.m.

Institution of Engineering Inspection, Leeds Branch. "The Reclamation by Impregnation of Porous Castings," by P. J. Young. Theological Library, Leeds Church Institute, Albion Place, Leeds, 1. 7.30 p.m.

Sheffield Metallurgical Association. "Electric Arc Furnaces—Hearths," by C. Hedley. B.I.S.R.A. Laboratories, Hoyle Street, Sheffield, 3. 7 p.m.

9th November

Institute of Metals. A Symposium on "The Mechanism of Phase Transformations in Metals." Royal Institution, Albemarle Street, London, W.1. 10 a.m.

Institute of Welding, Medway Section. "Recent Advances in the Welding of Aluminium Structures," by J. E. Tomlinson. The Clarendon Hotel, Gravesend. 7.30 p.m for 7.45 p.m.

Manchester Metallurgical Society. "Fuel-Fired Heating Furnaces," by Prof. M. W. Thring. Manchester Room of the Central Library, Manchester. 6.30 p.m.

10th November

Institute of British Foundrymen, Lincolnshire Branch. "Coreblowing," by G. W. Fearfield. Technical College, Lincoln. 7.15 p.m

Institute of Welding, North London Branch. "Automatic Argon Arc Welding of Low Alloy Steels," by F. J. Wilkinson. Manson House, Portland Place, London, W.1. 7 p.m. for 7.30 p.m

Institute of Welding, South London Branch. "Reclamation of Plant and Machinery by Welding." by G. G. Musted. 2, Savoy Hill, London, W.C.2. 6 p.m. for 6.30 p.m.

11th November

Incorporated Plant Engineers, Birmingham Branch. "Wire Ropes," by N. B. Yates. Imperial Hotel, Birmingham. 7.30 p.m.

Institution of Engineers and Shipbuilders in Scotland. Joint Meeting with the Aberdeen Mechanical Society. "Fatigue Research at M.E.R.L.," by C. E. Phillips. Robert Gordon's Technical College, Aberdeen. 7.45 p.m.

12th November

Institute of British Foundrymen, Scottish Branch. A non-ferrous paper by F. Hudson. Royal Technical College, Glasgow. 3 p.m.

14th November

Institute of Metals, Sheffield Local Section. "The Value of Non-Destructive Testing," by J. F. Hinsley. Engineering Lecture Theatre, The University, St. George's Square, Sheffield, 1. 7.30 p.m.

Institution of Engineering Inspection, East of Scotland Branch. "Crack Detection," by Solus Schall, Ltd. Royal British Hotel, Dundee. 7.30 p.m.

Institution of Engineering Inspection, Wolverhampton Branch. "Heat Treatment of Steel," by A. D. Hopkins. Compton Grange, Compton Road, Wolverhampton. 7.30 p.m.

15th November

Institute of British Foundrymen, Coventry and District Section. "Hot Blast Cupolas," by W. J. Driscoll. Coventry Technical College, Room A5. 7.30 p.m.

Institute of British Foundrymen, East Anglian Section. "Casting Defects," by J. L. Francis. Lecture Hall, Public Library, Old Foundry Road Entrance, Ipswich. 7.30 p.m.

Institution of Mechanical Engineers. Joint Meeting with the **Institution of Civil Engineers.** "The Development of a Mechanical Draught Water-cooling Tower," by L. Gilling Smith and G. J. Williamson. Institution of Civil Engineers, Great George Street, London, S.W.1. 5.30 p.m.

Institution of Mechanical Engineers. "Stress Analysis by Brittle Lacquers—Techniques and Applications." Applied Mechanics Group Discussion. 1, Birdcage Walk, London, S.W.1. 6.45 p.m.

Sheffield Metallurgical Association. "Boiler Feed Water and Associated Corrosion Problems," by J. Banks. B.I.S.R.A. Laboratories, Hoyle Street, Sheffield, 3. 7 p.m.

16th November

Incorporated Plant Engineers, Kent Branch. "Refrigeration and its Applications," by R. F. Brown. Bull Hotel, Rochester. 7 p.m.

Institute of British Foundrymen, London Branch. "Production of Cores and Moulds in British Foundries by the CO_2 Process," by A. Tipper. Waldorf Hotel, London, W.C.2. 7.30 p.m.

17th November

Liverpool Metallurgical Society. "High Purity Alloys of Iron," by Dr. N. P. Allen. Liverpool Engineering Society. 9, The Temple, Dale Street, Liverpool. 7 p.m.

18th November

Institution of Mechanical Engineers. Thomas Hawksley Lecture. "Properties of Matter at High Pressures," by Prof. D. M. Newitt. 1, Birdcage Walk, London, S.W.1. 5.30 p.m.

Society of Chemical Industry, Corrosion Group. Symposium on The Protection of Cable Sheathing: "The 'Phenol Corrosion' of Lead," by R. L. Davies and E. L. Coles; "Cathodic Protection of Telecommunications Cables," by J. Gerrard and J. R. Walters; "The Protection of Buried Power Cables," by J. H. Gosden; "The Behaviour of Aluminium Cable Sheaths," by P. A. Raine; "The Mechanism of Corrosion of Metal Pipes in Soils and Practical Methods of Prevention," by W. W. Robson and A. R. Taylor. Institution of Electrical Engineers, Savoy Place, London, W.C.2. 10 a.m., 2.30 p.m., and 5.15 p.m.

West of Scotland Iron and Steel Institute. "The Metallurgy of Nuclear Power Production," by Dr. A. B. McIntosh. 39, Elmbank Crescent, Glasgow. 6.45 p.m.

22nd November

Sheffield Metallurgical Association. "The Testing of Lubricants and Greases with particular reference to their use in the Metallurgical Industry," by Dr. H. E. Pristen. B.I.S.R.A. Laboratories, Hoyle Street, Sheffield, 3. 7 p.m.

Copper Tube Production

New I.C.I. Plant at Kirkby

Exterior view of one of the main shops

THE drawing of copper tubes comprises a series of operations whereby the diameter and wall thickness are reduced and the length is increased, so that the tube becomes progressively smaller, thinner and longer. Until the late 1920s, the reduction of diameter and wall thickness was achieved by pushing a tube over a steel bar, or mandrel, and then pulling it through a steel die. The diameter of the die was smaller than that of the tube, so that, when the tube and bar were pulled through the die, the diameter of the tube was reduced ; at the same time it was squeezed down on to the bar, thereby reducing the wall thickness.

This operation was somewhat lengthy, because after the drawing operation it was necessary to strip the tube from the mandrel. In the late 1920s, a method was evolved whereby a small steel plug was fixed in the die on the end of a long tie-rod ; the tube was threaded over the plug and tie-rod and then pulled through the die. The basic operation remained the same, with the plug acting as the steel bar, except that the tube moved over the plug, and there was, therefore, no need for a stripping operation. The development of the plug-drawing technique enabled further developments to take place, the principal one being the drawing of two tubes simultaneously.

Because of the rigidity of the mandrel, the original bar drawing method limited the length of the drawn tube to about 20 ft., but with plug drawing this restriction no longer applied. Benches became longer until, by 1939, machines up to 60 ft. in length were coming into operation. The value of increased length is two-fold. After each draw the tube becomes longer, and after two or three draws it fills the full length of the bench ; it is then necessary to cut the tube in half and to carry on drawing until the bench length is again fully occupied. This process might well be repeated several times, until as many as forty tubes are obtained from the original billet. It is obvious, then, that the longer the bench, the less is the need for cutting the tubes in half (with a consequent reduction in the amount of scrap produced). The second advantage is that of increased drawing speed. It was known that in the wire industry, copper could be drawn at high speeds, but to achieve these speeds longer benches were necessary to allow for acceleration and deceleration.

One of the limitations of plug drawing is that the tie-rod takes part of the drawing load ; when the length of the tie-rod becomes excessive, the elongation it undergoes causes trouble. Just before the war, I.C.I. began to experiment with the development of a plug which would remain stationary in the die without the need of a tie-rod. Success in achieving this meant that the drawing of tubes need no longer take place on a straight bench but could, like wire-drawing, be carried out on drums or blocks.

Design Considerations

Immediately after the war, I.C.I. gave serious consideration to the possibility of building a new copper tube drawing mill in which the plant would embody the advantages of all known techniques and enable them to be developed to a stage hitherto unachieved. The basic requirements were easily stated—to manufacture copper tubes in the longest possible lengths, employing drawbenches handling a number of tubes simultaneously, and then to draw the tubes on drums by a technique similar to wire drawing, all the time retaining the full weight of the tube processed from the original casting. It was realised that the limiting factor would be the handling of heavy weights and long lengths of tube between operations, and it was eventually decided that, from handling considerations, the longest practical length for a straight drawbench would be 150–170 ft., and the largest practicable drum diameter 4 ft. 6 in. to 5 ft. After practical trials it was found that the largest size of tubing which would be drawn on drums of this diameter would weigh 1 lb. per foot run : these factors fixed the unit weight of tube processed at 150 lb.

The basic essentials of the equipment for the new works at Kirkby, near Liverpool, were, therefore, straight drawbenches up to a maximum length of 150 ft., and drums (or draw blocks) for drawing to finished size. All drawbenches would draw three tubes at a time, the difficulty of tie-rod stretch being overcome by the use of floating plugs. This would enable drawing speeds of 450 ft./min. to be achieved, as compared with maximum

Casting of copper billets. In the background is the electric arc furnace which feeds the holding furnace with 5 tons of copper an hour

drawing speeds of 100 ft./min. on shorter benches. The retention of the full weight of the original tube would enable very long lengths to be drawn on the blocks, so it was decided to provide for speeds of up to 1,800 ft./min. To overcome handling problems, special cranes were devised to enable two, working in tandem, to lift tubes over 100 ft. long. The final layout included a main mass-production bay in which the foregoing equipment would be installed, and a second bay to deal with orders for small lots in special sizes, material being transferred to the second bay at the point where manufacture departed from the mass-production flow-line.

The planning of Kirkby was a major operation, both for the specialised staff of the Company and for the many suppliers of equipment who collaborated in producing novel units. Work studies were carried out on existing machines and the performance of the proposed equipment was synthesised. A provisional layout was then reproduced in a complete model of the factory, and the effect of operating under various conditions was studied; for example, each movement of each crane was represented by a length of coloured string, and plant was re-sited or work routes were adjusted to avoid excessive movement. Full-scale wooden models of parts of the major items of equipment were built, and design staffs carried out all the operations necessary on the finished equipment in order to ensure that controls were in the correct position, and to discover those factors which might prevent full utilisation of the plant. Films were made of the mock-ups, and these were studied and discussions held with the plant manufacturers.

Having decided on the main characteristics required of the equipment, and having studied the most modern equipment to date and the mock-ups of the proposed plant, the actual details of design still presented many difficulties, including the overriding problem of material movement. Floor transport was obviously an impossibility, except at the finishing end, and it would be necessary to rely completely on overhead cranes. This meant that the three long drawbenches would have to be installed in line, each with its separate overhead crane or cranes. But, to permit transfer of tubes from one bench to another, all these cranes would have to be on the same gantry, and this, it was realised, might result in excessive waiting time. So, in conjunction with the machine makers, double loading and discharge mechanisms were designed which eliminated the necessity for complete synchronisation of the overhead cranes and the drawbenches. Similarly, the problem of removing the coils from the draw blocks and supplying new material to them necessitated the design of a special rigid mast crane.

The need for a large number of overhead cranes meant that in each bay there would be approximately six cranes on the main track, which would prevent any one crane moving very far from its own area. It was therefore decided to instal a high-speed wall crane to run the full length of the building underneath the overhead cranes on the main track. It was also appreciated that a crane breakdown would seriously interfere with crane movements on the track, so a loft was built in the centre of the main mill into which broken-down cranes could be lifted clear of the main track for repair.

Discharge gear for 2500/500 ton forward extrusion press

Melting and Casting

The first step in the production of copper tubes is the melting and casting of the copper. Until Kirkby was built, copper billets in this country were cast from metal melted in small electric or gas-fired furnaces or in large reverberatory furnaces, used principally for the refining of copper from blister slabs. It was known that in America the arc furnace used in the steel industry had been modified for melting and casting copper, and after visits had been made to the United States it was decided to install a similar furnace at Kirkby. In this type of furnace the melting and pouring are virtually continuous, and the Efco unit at Kirkby is capable of melting copper ingots, cathode copper and copper scrap at a rate of 5 tons per hour.

From the arc furnaces, the copper runs down launders into a holding furnace of the Ajax-Wyatt type, which consists of a main cylindrical vessel looped in parallel with a smaller cylinder. The latter is surrounded by an induction heating coil and the metal circulates through the two sections of the furnace by convection. Besides stabilising the temperature of the metal, the holding furnace permits the introduction of other elements, such as phosphorus, when required. The copper is cast into moulds, which for the small billets are disposed round the periphery of a rotary water tank, one such

tank being situated on each side of the pourer, which can be tilted from side to side. The larger billets are individually water cooled. Ejection of the billet from the mould is automatic.

Production of Tube Shells

For making tubes under 2 in. diameter, there are two methods of processing the solid cast billets into a hollow tube—piercing and extrusion—both of which are carried out at a temperature in the neighbourhood of 850° C. Both of these are used at Kirkby.

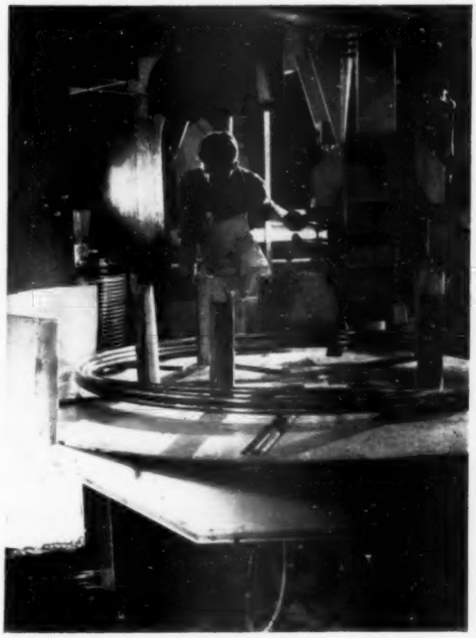
The hot piercer, which is located at one end of the mass production bay (A bay) deals with the smaller billets. The hot metal is rotated between obliquely set barrel rolls and simultaneously fed forward over a plug, which forces its way through the centre of the hot billet, producing a tubular form or shell.

It was known that the extrusion method—in which hot metal from the solid billet is forced through a die and over a mandrel so that the metal emerges in tubular form—had some advantages over piercing, and it was decided to produce most of the material at Kirkby by extrusion, using a Fielding and Platt 2,500/500 ton press. The piercer is, therefore, supplementary to the extrusion press. The extrusion press is situated in B bay, along with a 1,500 ton press, also by Fielding and Platt, for the back extrusion of billets for large diameter tubes and rollers. With back extrusion it is not always possible to obtain a surface free from scale, so at Kirkby all the hot-punched shells are machined before passing forward for cold drawing. The forward extrusion press can handle a 450 lb. billet, and extrudes a shell 30 ft. long, i.e., approximately three times the length and weight of the shell produced on the piercer. Before proceeding to the drawbenches the shells are water-cooled, pickled and washed, transfer between tanks being automatic.

Long Drawbenches

Weighing 150 lb. each, the tubes then pass to the rotary swaging machine and squeeze pointer, which points the tubes ready for drawing, and thence to No. 1 drawbench on which the longest length of tube drawn is 110 ft. Made by Head Wrightson, this bench is believed to be the largest in the trade and develops, with the aid of a 1,000 h.p. motor, a pull of 300,000 lb. Its maximum speed of drawing is 360 ft./min., three shells at a time. From this bench the tubes pass to No. 2 drawbench, which has a pull of 100,000 lb. and draws three tubes at a time at a maximum speed of 450 ft./min., the longest length being 160 ft. The tubes automatically roll off the bench for intermittent removal by overhead crane to drawbench No. 3, which is identical with No. 2. The products from this third drawbench may either be coiled and sent to drawblocks, or sawn and transferred to B bay oddments section, or to small domestic finishing benches in A bay.

160 ft. long tubes being drawn on No. 2 drawbench



Drawing coiled tube on a vertical drawblock

Drawing on Blocks

The coiled tubes from the straight drawbench operations are transferred to the Marshall Richards drawblocks, which continue to draw the full weight of the original tube at speeds up to 1,800 ft./min. Of the four blocks, two are operating on a horizontal axis, one has been converted to a vertical axis machine, with appreciable improvement in coil handling, and the fourth is in process of conversion. A feature of the drawblocks is the ease with which the coils are handled by the rigid mast crane, compared with the tricky operation of using two cranes and beams in tandem to convey the long straight lengths between drawbenches.

The remainder of A bay is occupied by machinery for various ancillary finishing operations, including decoiling, recoiling, straightening and cutting-off, bright annealing, dehydrating and crimping. In this area also the tubes are inspected, subjected to electronic flaw detection, and pressure tested prior to packaging in the warehouse.

Large and Special Tubes

There are few mass-production lines for tubes over 2 in. in diameter, but the demand for miscellaneous items does, in fact, go up to 20 in. As well as providing equipment to produce small-bore oddments, therefore, it was also necessary to design and install plant for the manu-

Coiled tube being transported by rigid mast crane

facture of relatively small batches of larger tubes, from 2 in. to 20 in. in diameter.

At the time when the decision to build at Kirkby was taken, the traditional method of drawing tubes on a steel mandrel, slow and extravagant of labour, was still used for all large diameter tubes. It was decided, however, that equipment should be provided at Kirkby for the plug drawing of tubes up to 12 in. in diameter. The needs of the equipment were fundamentally different from those governing the mass production of small diameter tubes. Because of the small number of tubes required in each batch, the incidence of tool change was much greater; indeed, it was more necessary to design machines which enabled tool changing to be effected quickly than to provide high drawing speeds. Drawing speeds were, therefore, kept low, compared with mass-production equipment, but to ensure that the machine could be kept occupied for as long as possible a great deal of attention was paid to the methods of tool change. Special dieheads were designed, and methods were evolved for the rapid supply of tools for the benches.

The bay in which large size tubes and oddments are produced (B bay) houses the extrusion presses and associated furnace equipment, two 70 ft. Head Wrightson drawbenches, and Wellman Smith-Owen benches which have been specially developed for plug drawing tubes up to 14 in. diameter. It was realised that for tubes larger than 12 in. in diameter the technical advantages still lay with mandrel drawing, but by mechanisation and simplification of operations on the hydraulic bench installed for mandrel drawing tubes up to 17 in. diameter, labour utilisation has been greatly improved and physical effort much reduced.

Copper Rollers

Among the tube products for which I.C.I. has become well-known are copper rollers for textile printing and electrodeposited rollers for textile and paper printing. The work was originally carried out at the Broughton Copper Works, and on its transfer to Kirkby the solid roller department was modernised and the electrodepositing department completely re-equipped. Solid rollers are produced from the cast billet on the back extrusion press, like the shells for large tubes, but during the punching operation a key is formed in the bore of the shell. The shell is then cold rolled, fitted to an exact position on a tapered mandrel by mechanical hammering, turned to size and polished. The finish of the polished roller is of the greatest importance, and at Kirkby, special equipment has been designed to ensure a consistently high quality of finish, which is checked by a Talysurf machine. This gives a graphical picture of the surface correct to one micro-inch. Accuracy of dimension is also of the greatest importance because of the use of rollers in multi-colour processes, and the closest control is therefore maintained at all stages of production.

Copper deposited on either a copper or cast iron base is also used for textile printing, and during recent years there has been a big increase in the demand for electrodeposited rollers for photogravure printing. The equipment installed at Kirkby is the most modern available, and by close control of the electrolyte and the current density a deposit of high quality is achieved. After deposition the rollers are finished in the same way as solid copper rollers.

"Integron" Finned Tubing

A recent development in tube fabrication has been the "Integron" finned heat exchange tube. As opposed to types on which the fin is wound or brazed on to the tube, the "Integron" fin is integral with the tube. It is formed by rolling a thick gauge tube so that most of the metal in the wall is displaced into the fins. "Integron" is produced with either a high or low fin, depending on the use to which it is to be put. Such a tube has obvious heat transfer advantages and is particularly suitable when it is necessary for the finned tube to be bent, or where excessive vibration is encountered, because it is impossible for the fins to become loosened from the tube.

Finned tubes are produced in copper, aluminium and a number of copper alloys. It is also possible to produce bi-metal finned tubes, in which the fins and the outer wall are in copper or aluminium and the inside of the tube is in steel, titanium or any of the copper alloys.

Another tube fabricating operation carried out at Kirkby is the manufacture of cable sockets from copper tubes.

Design and Construction

The design of buildings to house the most up-to-date drawing plant in the world posed special problems. The layout of machinery, and particularly the need to place the three largest draw-benches end to end, called for a main production unit a third of a mile long; a second over-riding requirement was the necessity to avoid ledges and lattice girders which would harbour dust.

The design finally adopted for the main production unit comprised an all-welded double-bay structure, each bay 1,530 ft. long and 90 ft. wide, with an inside height of a clear 30 ft. to the eaves. To avoid dust traps the Portal frame construction was adopted—a feature with the additional advantage of enabling overhead cranes to be housed in the roof space while still retaining the maximum lift required for working. One of the bays accommodates five overhead cranes and one rigid mast crane, the other five overhead and two rigid mast cranes. Both bays are equipped with travelling jibs, each 4-tons on a 15 ft. arm, which run the full length of the building on each side of the valley and pass underneath the overhead cranes. The gables are designed to carry 5-ton Semi-Goliath cranes.

A third bay was required to house service sections. To reduce volume, this was designed as a single-storey

flat-roof structure, 28 ft. wide and 18 ft. high, running almost the full length of the main building. Smaller production units (casting shop and roller department) and ancillary units such as offices, stores, canteen, boiler house and fire station, were housed in separate buildings. All the buildings have 11 in. cavity walls and 6 in reinforced controlled concrete floor bases with ½-in. granite finish, powdered with carborundum and case-hardened. The total superficial area of the buildings is more than 470,000 sq. ft., and the cubic capacity more than 19 million cubic feet.

Heating and Lighting

THE question of space heating the main mill, of 13,788,000 cu. ft. capacity, was a major problem. As a step towards solving it the roof was clad with corrugated aluminium alloy sheets, lined with ½-in. insulating boards and in inner layer of 0·009 in. aluminium foil, giving a coefficient of thermal transmittance of the order of 0·2. Walls were also lined with ½-in. insulating boards. To minimise the temperature gradient from floor to roof it was decided to install radiant panel heating served by high-pressure hot water; this was chosen rather than steam to eliminate steam traps and to avoid the necessity for make-up or a water purification system.

Special attention was given to natural lighting. To reduce the total area of roof lights, and so limit heat loss, it was agreed to adopt star lighting, using corrugated Perspex panels. This system, as well as ensuring uniform light distribution, offered the advantages of requiring no additional steelwork and of providing watertight and dustproof lights.

Cooling Water Supplies

The demand for cooling water used in production processes—unusually heavy at Kirkby—is catered for by collecting in a central reservoir all storm water from the roof of the seven-acre main mill. This reservoir, with a capacity of 1½-million gallons, is normally sufficient to provide all the cooling water used in production. It is also a source of water for fire-fighting purposes, the pumps for which are operated by remote control from the fire station.

New Fescol Factory at Huddersfield

THE opening by the Mayor of a new factory at Leeds Road, Huddersfield, last month, is the latest stage in the development of Fescol, Ltd., which was founded 35 years ago by Mr. R. J. Fletcher, under the name of The Fletcher Electro Salvage Co. Ltd. The name was abbreviated a few years later to Fescol, which is now identified with the application of certain non-ferrous metals, particularly nickel and chromium, to already-fabricated metal components so that the superimposed material becomes an integral part of the component.

The Company first operated at Penarth Street, in South East London, but by 1926 larger premises were acquired in Grosvenor Road, Westminster. To meet the demand from the industrial Midlands and North of England, a factory was opened in Huddersfield in 1934, and in 1935 a company (Société Fescol) was formed in France, with works at Gaillonet, Seine-et-Oise, and an office in Paris, to operate the process under licence. In 1938 increasing business again necessitated moving the London factory to the present site at North Road, London N.7, where the plant now includes a modern machine shop, so that components can be machined after treatment. The Huddersfield factory was moved to a larger site in 1941, and the post-war years have seen the opening of the first Scottish factory at Port Glasgow, and a factory at Brownhills, Staffs.

Process Developments

The process was initially employed to make good such deficiencies as might be caused by wear and tear or by faulty machining, but new components having a comparatively cheap and easily worked base can often be greatly improved, also, by Fescolising.

One of the major problems formerly encountered in the production of electrodeposits for engineering purposes was to obtain adequate adhesion on light alloys, but after intensive research the Company solved the problem by evolving a process which enabled the chromium to be deposited on a limited range of light alloys. Experimental work was undertaken for one of the major aircraft companies, and a special plant was installed in 1951, in the former Huddersfield works, to carry out this work.

After further investigation an improved process has now been developed which enables the company to deposit chromium direct on to all known light alloys so that the deposited metal becomes an integral part of the base metal. The new process has received Ministry of Supply approval for use on aluminium and aluminium

General view of the workshop with the chromium baths in the left foreground

alloys used in the construction of aircraft and aircraft equipment.

The Fescol process differs from many other known commercial methods in that the chromium is deposited directly on to the light alloy, and does not rely on an undercoat of a second metal to ensure adhesion. In the new Huddersfield factory, provision has been made for special plant to carry out this type of work.

The Huddersfield Works

The new factory, which has a floor area of nearly 14,000 sq. ft., is approximately twice the size of the previous Huddersfield works at Cable Street, which the Company had occupied for 14 years. Most of the plant in the new works has been transferred from the old factory, but the greater availability of space has allowed a far more efficient layout and the inclusion of modern electric hoists and other handling aids.

Known as Springbank Works, the factory has a two-storey frontage—the ground floor comprising offices and laboratories, while on the first floor is a canteen for the workpeople and a file-room and drying-room. The main works, which is at the rear, covers an area of over 10,000 sq. ft. and includes a chromium depositing shop, nickel depositing shop, stores and inspection departments.

Chromium Depositing Shop.

The six vats for chromium deposition are all installed in special pits to give a common working height. Above them is an electric hoist block, with a capacity of one ton, and several smaller hoists. The chromium shop can deal with shafts of up to 8 ft. in length, although 4 ft. 6 in. is the maximum length which can be treated in one operation. Each vat can deal with a superficial area of about 6 sq. ft. at one time.

Power is supplied to each vat by an independent oil-immersed Westalite rectifier set—five sets each have an output of 1,500 amps at 12 volts, and one has an output of 1,000 amps at 12 volts. Each rectifier set is a self-contained unit, with mains and auto-transformers and control gear.

Fumes from the vats are extracted through ducting by high speed fans, and to ensure an adequate replacement supply of fresh air, four louvred inlet vents with sliding fronts are provided in the walls. The vents are positioned so that cool air entering the building has first to pass the transformers and rectifiers adjacent to the vats and so cool them.

Nickel Depositing Shop.

The vats for the deposition of nickel are also installed in pits to give the same working height. The main electric hoist block serving the vats is of 2 tons capacity, and the size of shafts which can be accommodated is the same as in the chromium shop.

The power supply is obtained through motor generator sets having a total output of 3,000 amps at 10 volts. In case of a power supply failure, accumulators with a capacity of 4,000 amps at 10-hour rate of discharge have been installed.

Machine Shop.

A machine shop is included in the works for machining of certain components before and after deposition.

General.

The brick-built factory has a reinforced concrete floor and roof. In the deposition areas the flooring and pit linings are of acid-resisting asphalt. Except for the offices, the building is painted throughout with chlorinated rubber paint. Ducts are provided in the concrete floor to accommodate the gas, water, compressed air and electricity supplies to the deposition vats.

Largest Casting Made

For a number of years English Steel Corporation, Ltd., Sheffield, have been producing the heaviest steel castings made in the British Commonwealth. One which was cast at the company's Grimesthorpe Foundry on Monday, 26th September, is the largest the company has ever produced. The casting, a 166-ton forging press Entablature, measures 28 ft. 6 in. in length, 14 ft. 2 in. in height and 8 ft. 6 in. in width—2 ft. longer, and 1 ft. higher than the record-breaking 185-ton press castings for America which were made at Grimesthorpe in 1953.

During the 25 minute casting operation and the subsequent " feeding ", 225 tons of steel were used. The bulk of it, 194 tons, came from three ladles teeming simultaneously, whilst the remainder was added to ensure that the casting was sound. To produce this quantity of steel, three Siemens open-hearth furnaces, and three electric arc furnaces, were required, the former being tapped simultaneously. The pattern used, one of the largest ever made, was in ten sections. It had taken three months to build, and required three journeys to bring it from the maker's works at Batley to Sheffield. The casting will now be left to cool for a month before being lifted from the pit for heat treatment, fettling and machining.

Kelvin Hughes Components

Kelvin & Hughes, Ltd., has now entered the component market with a wide range of electrical and optical equipment. Many of the components—which are used in Kelvin Hughes marine, aviation and industrial instruments—can be manufactured to suit special requirements. The list of components now available from the company includes instrument motors, barometric capsules, teletorque synchronous transmission units, ultrasonic magnetostrictive oscillators, sine/cosine potentiometers, gyroscopes, optical components and magnetic recording heads.

A Method of Preparing Iron Powder for Permanent Magnets

By E. H. Carman, Ph.D., M.Sc., A.Inst.P.*

An apparatus for the hydrogen reduction of small quantities of iron oxide at temperatures between 250 and 350° C. is described, and curves showing the relationship between reduction time and reduction temperature, and between particle size and reduction temperature are given. The smallest iron particle size obtainable by the method is that of the oxide particles employed.

In recent years a number of papers have been published on the properties of iron powder magnets prepared from hydrogen-reduced iron salts. Notable among these are the investigations of Bertout[1, 2] on the dependence of coercive force on particle size, and Weil[3], who has studied the variation of coercive force with the density of packing of the powders. Despite the increasing volume of material of this kind, there still appears to be a lack of detailed information regarding the conditions and methods of preparation of the iron powders. The present paper gives such details and is written in the hope that it may prove useful to some of the experimenters who wish to prepare small quantities of the fine powders under controlled conditions. A hydrogen recirculating apparatus, capable of producing about 35 g. of pure iron at a time, has been developed for this purpose.

Preliminary experiments with a typical grade of commercial ferric oxide show that for a reduction temperature range 250–350° C., a corresponding particle size range 250–500 Å is to be expected. Compacts of these powders have coercive forces up to 600 oersted and (BH)max up to $0{\cdot}8 \times 10^6$ gauss-oersted for optimum density of packing.

The Reducing Chamber

The apparatus has been designed for the removal of oxygen from iron oxide at temperatures below 350° C. Oxide for reduction is placed in shallow nickel boats over which dry hydrogen flows. After reduction, the boats are withdrawn into petroleum ether to prevent the iron powder coming into contact with atmospheric oxygen. Fig. 1 illustrates the method of supporting the powder in the reducing chamber, together with the device for removing the sample.

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The six nickel boats *A* are 45 mm. long, 35 mm. wide and 10 mm. deep ; they are supported by the base of a brass insert *B* through which hydrogen passes. The insert consists of a rectangular tube measuring 37mm. × 60 cm. fitted with circular end plates. The plates are machined to fit within the cylindrical Pyrex-glass sheath *C*, with their diameter normal to its axis and with clearance to allow for thermal expansion. Thus the hydrogen flow is restricted to the rectangular space immediately above the boats.

The glass sheath has an inside diameter of 6 cm. and is 105 cm. long. One end is formed to take a ½-in. inside diameter rubber tube, while the other is closed with a large rubber stopper. Hydrogen enters at the inlet *D*, passes over the pre-heating coil *E*, and leaves the chamber after passing round a spiral baffle directing the flow against the glass wall, which is cooled by the separate external water jacket *F*.

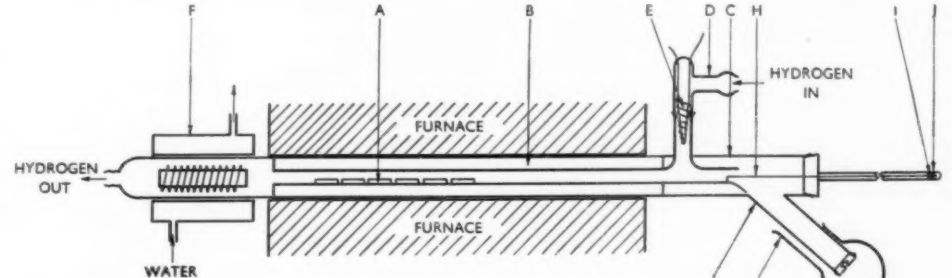
The main heat source is from the furnace surrounding the reducing chamber.

Device for Removing Sample

To facilitate removal of the boats from the chamber, the base of the insert extends beyond the end plate and is bent to form a lead-in to the glass shute *G*. The boats are withdrawn by means of a long stainless-steel rod *H*, bent at one end to form a short hook ; the other end is screwed into a cylindrical mild-steel pellet *I*. The pellet is made to slide within the long (85 cm.) glass tube *J* by manipulating a pair of strong magnets against its outer surface. Flat surfaces on the pellet enable it to be rotated, so that by using the magnets the hook can be made to move along the insert, rotating upwards to clear the front of the nearest boat and then downwards to engage it.

It is not necessary to interrupt the hydrogen flow to remove the boats from the apparatus. With the aid of a

Fig. 1. The reducing chamber



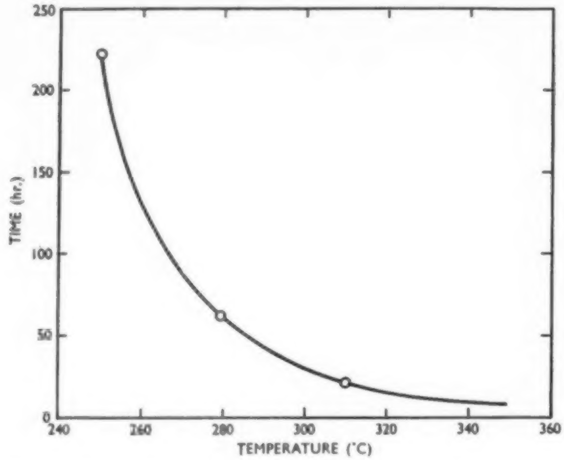


Fig 2.—Time for complete reduct'on at temperatures between 250 and 350°C.

further innovation they may be removed one by one at any stage of reduction. A synthetic rubber stopper is fitted to the lower end of the shute G. This stopper has a brass core recessed at its outer face to engage with a key rigidly attached to the base of the flask K, filled, for example, with petroleum ether. The key is engaged by rotating the flask through a small angle about its axis. The stopper can then be removed clear of the end of the shute, which remains immersed in the protective liquid, and the first boat is ready for removal.

The Recirculating System

A rotary fan passes dry hydrogen at approximately 600 litres/hr. through a flow gauge, pre-heating element, reducing chamber, water cooler, silica gel dryers and phosphorus pentoxide dryers.

The silica gel dryers are constructed from glass tubing 5 cm. in dia. and 30 cm. long. They are effective in the early stages of reduction when the vapour pressure of water in the system is high. In the later stages the quantity of vapour entering the dryers is considerably reduced, and absorption continues by phosphorus pentoxide placed in two 45 cm. nickel boats within the limbs of a U-tube.

Hydrogen consumed in the reducing chamber is replaced from a gasometer-type reservoir. This consists of an inverted one litre beaker within a two litre beaker almost filled with oil. A glass tube fused into the base of the inverted beaker connects it with the apparatus. The reservoir holds about 800 ml. of gas which is replaced, when exhausted, with cylinder hydrogen after removal of oxygen and water vapour.

Temperature Control

With the present apparatus, the rapid hydrogen flow and lack of space for the installation of an adequate system of thermo-couples lead to difficulty in attaining a uniform temperature throughout the sample. This is overcome by supplying energy to the furnace at predetermined conditions.

The reducing chamber is surrounded by a furnace having four heating elements along its length. A rheostat is connected in series with each element, the four circuits so formed being connected in parallel. By adjusting the rheostats any desired temperature distribution along the furnace can be obtained. The energy supply to the furnace is controlled by a Cambridge regulator with the thermo-couple permanently placed in the centre of the " dead space " above the brass insert (B, Fig. 1).

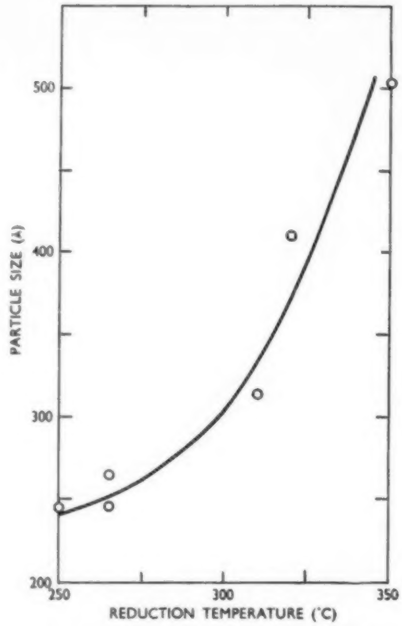


Fig. 3.—Variation of iron particle size with reduction temperature

The arrangement just described can be adjusted to provide a constant uniform temperature in the space surrounding the insert. However, if cold hydrogen enters the insert a considerably lower temperature exists in it, resulting in a significant gradient in the sample. The gradient is eliminated by supplying energy at a continuous predetermined rate to the preheating element (E, Fig. 1), so that the temperatures in the hydrogen stream and dead space are the same. For the preheater adjustments the rubber stopper supporting the extraction assembly is replaced by a similar stopper fitted with a system of thermo-couples designed to register temperatures at several points in the dead space and hydrogen stream. Adjustments to the various current sources are then made until all the thermo-couples register the same value at the pyrometer. Thus, for a given uniform temperature and hydrogen flow, the rate of energy supply to the preheater is known.

Discussion of the Method

Useful data have been obtained by recording the progress of reduction during operation of the apparatus at various temperatures. Three relationships are of importance, viz., the time taken for complete reduction as a function of temperature, and the dependence of the particle size of the reduced iron on the reduction temperature and the size of the oxide particles, respectively.

Temperature-Time Relationship for Complete Reduction

Reductions have been carried out at three well-separated temperatures on similar samples of commercial ferric oxide. The time taken for complete reduction is

(a)

(b)

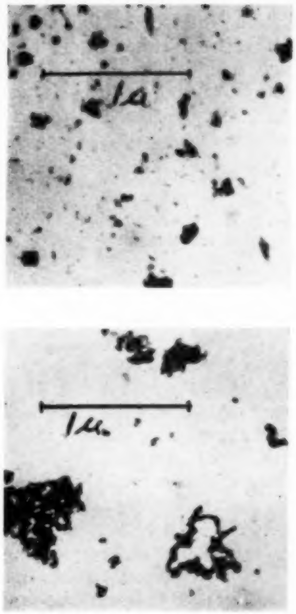


Fig. 4.—Precipitated ferric oxide : (a) before reduction ; (b) after reduction.

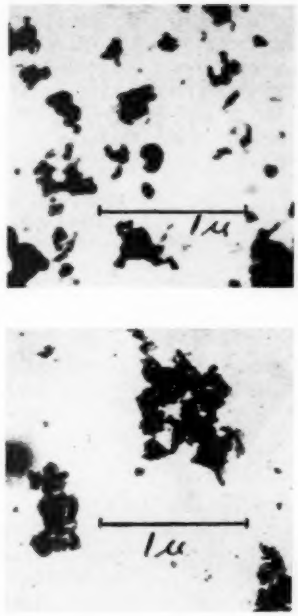


Fig. 5.—Thermally decomposed ferric formate : (a) before reduction ; (b) after reduction.

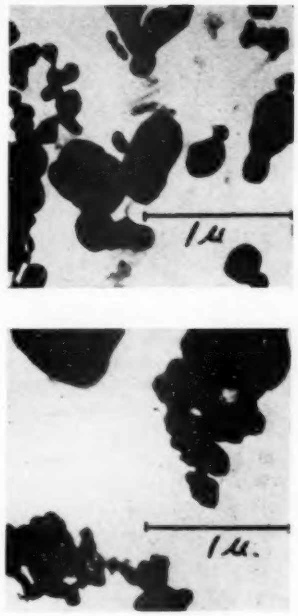


Fig. 6.—Rouge : (a) before reduction; (b) after reduction.

(a)

(b)

determined by observing the rate of absorption of successive 800 ml. hydrogen charges. At the end point, this rate becomes constant and equal to the previously determined rate of leak from the system. Reduction times and temperatures are as follows :—

Temperature (° C.)	Time (hr.)
250	223
280	63
310	22

Assuming the mechanism of reduction to be one of diffusion of hydrogen into the oxide particles, the abovementioned data should fit a relation of the type

$$r = k\ e^{-Q/(RT)}$$

where r is the rate of reduction, Q the activation energy of the reduction process, R the gas constant, k a constant and T the absolute temperature. Furthermore, if the activation energy is independent of the temperature, a linear relation should exist between log r and H/T. In the present case an accurate linear relation is obtained, resulting in the following interpolation formula :—

$$\log r = 7 \cdot 55 - \frac{5{,}162}{T}$$

From this, points on the temperature-reduction time curve (Fig. 2) are found. The three points employed in the derivation are shown, while validity for extrapolation to 350° C. is assumed. This relationship is generally dependent on the rate of hydrogen flow per gram of oxide, but for sufficiently high flow rates the dependency is negligible. In the present case it was not possible significantly to decrease the time for complete reduction at a particular temperature by doubling the flow rate.

Particle Size versus Reducing Temperature

A curve showing the relationship between iron particle size and reducing temperature for seven runs in the temperature range 250–350° C. appears in Fig. 3. These powders all originate from the same oxide sample. The particle sizes have been deduced by examining back reflection X-ray exposures of the powders with a Dobson microphotometer in the usual way.

Relation Between Oxide Particle Size and Iron Particle Size

Success with the method is limited by the oxide materials employed. Experiments to demonstrate the importance of oxide particle size indicate that the iron particle size can be no smaller than the oxide size. For these experiments samples of precipitated ferric oxide, thermally decomposed ferric formate, and rouge were placed in separate boats and the reductions were carried out simultaneously at 280° C., thus ensuring comparable reduction conditions and negligible particle growth during reduction.

Figs. 4–6 show electron micrographs of samples of oxides from various sources before and after reduction. It will be noted that there is a qualitative relationship

TABLE I.—PARTICLE SIZE (Å).

	Oxide	Iron
Precipitated Fe_2O_3	110	180
Thermally Decomposed Ferric Formate	280	240
Rouge	1,600	1,200

between the size and shape of the respective oxide and iron particles. A quantitative comparison for arithmetic means of average diameters resulting from an examination of several exposures from each sample is as shown in Table I. These data provide a good check on the corresponding X-ray value of 250 Å for precipitated Fe_2O_3, Fig. 3, and suggest that the iron particles in that case are most likely separate crystallites.

Acknowledgments

The present work forms part of a programme carried out by the author while in possession of a Research Scholarship from the University of Melbourne. The author wishes to thank Professor J. Neill Greenwood and Dr. W. A. Wood for their continued interest in the work. His thanks are also due to Dr. R. I. Garrod of The Aeronautical Research Laboratories, Department of Supply, Fishermen's Bend, for assistance with the electron microscope exposures.

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Norton Silver Jubilee Celebrations

NORTON GRINDING WHEEL CO., LTD., announce a £500,000 expansion programme over the next three years, involving large scale additions to the factory and new offices. This news was recently made public by Mr. Milton P. Higgins, President of the parent Norton Company of Worcester, Mass., U.S.A., at the Company's 12th Service Award Dinner which coincided with its 25th Anniversary. The expansion programme will provide more factory space, which will not only give increased production facilities, but will also enable an even wider range of products to be manufactured, including refractory products for atomic energy work. Mr. Higgins confirmed his belief in the growing demand for abrasive and refractory products, and in the ability of the Norton team to meet that demand with Norton products. "Unless you have courage to build for the future," he said during his speech, "you may as well give up."

Mr. Higgins, along with Mr. A. Donald Kelso, another of the Company's American directors, had come over to this country in connection with the Silver Jubilee celebrations. The first Norton grinding wheel plant was set up in Worcester, Mass., in 1885, and the formation of the British Company in 1930 was a natural and logical development, since Norton products had been distributed in this country by Alfred Herbert, Ltd., from the beginning of the century. The original building was completed in 1931, and was soon turning out both vitrified and resinoid wheels. Within three years the first tunnel kiln had been installed, and continuous firing was the standard production routine. Through the years, capacity and equipment have grown to meet the ever increasing demand, but the emphasis has not been on quantity alone: quality control has always been of paramount importance. Backed by the scientific knowledge and technical skill of the largest abrasive research laboratory in the world, manufacturing processes have been constantly attuned to produce better wheels, and to provide operators throughout the country with help and advice on how to get the best out of them. This policy of service to the user has called for a Sales Engineering Department, whose experts are always available to give technical advice and to assist in trials to find the very best wheel for a particular job.

To-day the Company produces a huge range of grinding wheels, both in specification and size—from $\frac{1}{8}$ in. in diameter and a fraction of an ounce in weight, to 72 in. across and weighing over 2 tons. These large segmental wheels may be 18 in. thick, while there are cut-off wheels only $\frac{1}{32}$ in. thick. In addition to straight wheels, large numbers are made to various shapes—tapered, cupped and bevelled—to do all sorts of specialised jobs, while, finally, there are many abrasive products other than wheels. These include rubbing bricks and sticks, hones, oilstones and sharpening stones, all produced at the Welwyn Garden City factory.

When it is considered that, apart from shape and size, grinding wheels can be made from six or seven different abrasive materials, controlled to dozens of different grit sizes and held together with a number of different bonding materials, it will be realised that the business of selecting the right specification from the many thousand possible combinations is a highly specialised one, and that the job of organising their efficient production is no mean task.

Norton policy has always been based on the knowledge that a successful business depends on the happy co-operation of everyone in the firm, and it is an indication of the high standard of respect for all employees, and of care and thought for their welfare, that 15% of the employees have been with Norton for 10–15 years, 26% for more than 15 years, and several people for the full quarter century.

Various celebrations have been held to celebrate the Silver Jubilee, including an Open House Week, the special Annual Award Dinner, and the big "family" celebration when a party of more than a 1,000 went down to Margate for the day.

Immingham Dock Outer Gate Launched

ON Friday, September 16th 1955, Head Wrightsons' were again able to demonstrate how their geographical location on the River Tees enables them to deliver completed dock gates direct from their constructional shops to site, when the first leaf of a new pair, built for the British Transport Commission, Humber Ports, was launched. The launching ceremony was performed by Mrs. H. L. Hopkins. Mr. Hopkins, who was also present is Port Master at Grimsby Docks. Also present were Sir John Wrightson, Bt., Vice-Chairman of Head Wrightson & Co., Ltd.; from the Humber Ports, Mr. S. A. Finnis, Chief Docks Manager and Mrs Finnis, Mr. G. D. Lloyd, Chief Docks Engineer and Mrs. Lloyd ; and senior officials of Head Wrightson & Co., Ltd. Head, Wrightson & Co., were responsible for the design, fabrication and building of the gates to the Commission's specification on the Company's slipways on the River Tees, adjoining their constructional shops. After launching, tugs were waiting to tow the gate to Immingham, where it will be stepped into position under supervision of the Company's engineers.

CO-OPERATIVE RESEARCH

Survey of the Activities of the Research Associations

B.C.R.A. B.S.C.R.A.
B.C.I.R.A. B.N.F.M.R.A.
P.E.R.A. B.W.R.A.
B.I.S.R.A.

The British Ceramic Research Association

By A. E. Dodd
Information Officer

ALTHOUGH accurate figures are not available, it is probable that between 5% and 10% of the refractories produced in this country are used in the non-ferrous metals industry. Because some important non-ferrous extraction processes are utilised, in this country, by a single firm, whereas simple melting in crucibles is so widespread that the conditions of use cannot be reduced to a single "norm," research on refractories for the non-ferrous metals industry would be difficult to organise. Several items in the general research programme of the Refractories Division of the Research Association should be of some interest to the non-ferrous metals industry, however; for example, the work carried out in the early days of the Research Association on silica refractories led to a general improvement in the uniformity of firing of these products, and the development work on chrome-magnesite bricks, undertaken for the Research Association by the late Dr. W. J. Rees and by T. R. Lynam at Sheffield University, provided much of the data on which British manufacturers have since built up our basic-refractories industry. General research on the properties of fireclay refractories has similarly led to an improvement in those products, and this has benefited users in fields other than those for which the research was primarily carried out.

Of more specific interest to one section of the non-ferrous metals industry, will be a study that the Research Association (H. M. Richardson and G. R. Rigby[1]) recently made of the reactions of zinc and zinc oxide with firebricks.

The Action of Metallic Zinc on Fireclay Refractories

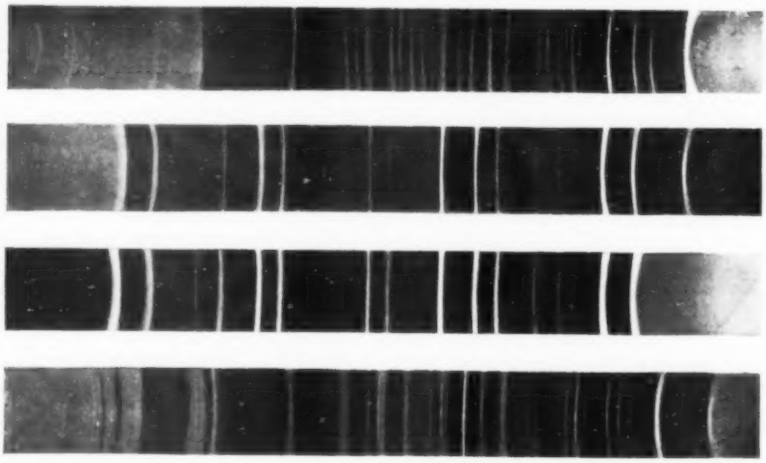
It is not easy to devise a laboratory test that will reveal the manner in which metallic zinc may react with fireclay material; molten zinc does not wet firebrick and will not readily penetrate its pores. When zinc was heated at 800° C. in contact with a firebrick in an atmosphere of nitrogen, the zinc remained on the surface of the brick and there was no reaction. An attempt was then made to induce zinc vapour to condense in the pores of a firebrick, but it was not until the following technique was tried that success was achieved. A hole was drilled into one end of a firebrick cylinder, zinc was introduced into the hole and the end was sealed with refractory cement; this specimen was then placed in a vertical tube furnace so that the central core containing the zinc was in the hot zone, at 1,100° C., while the top of the cylinder was only at 300° C.; nitrogen was passed through the furnace during the heating and cooling. In this way, all the zinc was made to volatilise and pass through the pores of the brick. Examination of the cooled specimen showed that some zinc remained as very small droplets in the pores, but that most had been deposited on the outside of the firebrick cylinder and on the furnace walls. The firebrick cylinder was not disintegrated; the test was repeated at 1,000° C. and at 1,050° C. with the same negative result. It was evident that the great difference in expansion between metallic zinc and firebrick had not been able to exert stress on the pore structure of the refractory, the smallness of the zinc droplets permitting them to expand without restriction in the comparatively large pores in the brick.

Metallic zinc might also disintegrate a refractory in consequence of the expansile forces resulting from its oxidation. To test this, several specimens were impregnated with zinc and subsequently heated in oxygen at temperatures up to 800° C.; the rate of oxidation was slow (any attempt to increase the rate caused the zinc to volatilise through the pores of the firebrick) and the growth of the zinc droplets as they were oxidised did not affect the refractory.

These experiments indicated that metallic zinc, either of itself or during its oxidation, will not disintegrate a fireclay refractory under normal conditions.

The Action of Zinc Oxide on Fireclay Refractories

Samples of siliceous (21% Al_2O_3), normal (32% Al_2O_3) and aluminous (42% Al_2O_3) firebricks were finely ground, mixed with zinc oxide, and moulded into cylinders; the latter were then heated in air for two hours at temperatures varying from 800° C. to 1,300° C. The fired specimens were examined by X-ray to determine the crystal phases present. The results indicated that reaction first took place between the zinc oxide and the firebricks in the 800°–1,000° C. temperature range. The siliceous brick reacted slightly at 800° C. to form a small amount



(1) Cristobalite

(2) Reaction product between ZnO and firebrick

(3) Zinc aluminate

(4) Mullite

Fig. 1. X-ray photographs showing the course of the reaction between zinc oxide and a 32% Al_2O_3 firebrick; the reaction product contains zinc aluminate and cristobalite, mullite is absent.

of zinc silicate, but the 32% Al_2O_3 firebrick was slightly less reactive ; zinc silicate was first identified with this product after the mixtures had been heated to 900° C. The initial reaction product of the aluminous firebrick was the spinel, zinc aluminate, first observed at 900° C., and not zinc silicate, but both zinc aluminate and silicate appeared in the samples after they had been heated to 1,000° C. In many samples, zinc silicate was present after heat treatment at low temperatures but was no longer identified after the same samples had been heated at higher temperatures ; this instability of zinc silicate at higher temperatures was most marked with the mixtures containing aluminous firebrick, but it was also apparent with mixtures containing the siliceous brick. Although Rieke and Pasch[2] have also reported the simultaneous appearance of zinc silicate with zinc aluminate when zinc oxide reacted with kaolin, the present results indicated that zinc silicate and mullite cannot exist together when equilibrium is attained, since at 1,200–1,300° C. zinc silicate and mullite were not identified together in the same sample. Mullite reacted more readily than the quartz or the cristobalite constituents of the original bricks with the zinc oxide. (See Fig. 1.)

In an attempt to determine the relative rates of reaction of zinc oxide with silica and alumina, mixtures of zinc oxide with hydrated alumina and with hydrated silica were heated in the temperature range 700–1,200° C. It was found that a small amount of zinc aluminate was formed at 700° C., but no zinc silicate could be identified at this temperature. At 800° C. the reaction between the hydrated silica and zinc oxide was well advanced but had not reached completion. Both reactions were completed at about 1,050° C., but there was no marked difference in the rates of the reactions to indicate why zinc silicate appeared before equilibrium was attained in the reaction between zinc oxide and mullite.

These findings help to explain the general preference for siliceous fireclays for use in horizontal zinc retorts, the quartz present in such clays being less reactive towards zinc oxide than the mullite that would be formed in more aluminous retorts ; another reason for the preference for siliceous retorts is their greater stability under load under the conditions of use.

Chrome-Magnesite Bricks in Copper Smelting Furnaces

The research carried out on the "bursting-expansion" of chrome-magnesite refractories—described in some detail in earlier reviews in this series—has a direct bearing on the behaviour of this type of refractory in copper reverberatory smelting-furnaces. A 40-ton furnace of this type examined a few years ago had a magnesite bottom and side-walls to the slag line, the upper side-walls and roof being built of chrome-magnesite. The slag carried in this furnace contained nearly 30% of iron oxide and, in an area repeatedly splashed with this slag by the air-blast, the chrome-magnesite bricks had expanded and eventually caused the roof to fail. This expansion, as we have previously stated, is a result of solid solution of magnetite (Fe_3O_4) in the complex chrome-spinel (Mg, Fe) (Al, Cr, Fe)$_2O_4$ crystals that form the bulk of a normal chrome-magnesite refractory. So far, no method has been found to prevent this solid solution other than the obvious one of reducing the amount of chrome-spinel present in the refractory, as is done in the magnesite-chrome brick. For some purposes, the latter type of refractory has given improved service.

Some Other Items of Research

The practice of examining industrial furnaces immediately they are taken off gas for repair has paid good dividends in providing concrete evidence of the principal causes of wear of refractories under a specific set of conditions. Over eighty iron blast-furnaces have now been examined in this way, some cursorily, some in very great detail. Members of the research staff have also examined numerous steel furnaces, gas retorts, ships' boilers and other installations.

In the laboratory, work has continued on the fundamental causes of the bursting of chrome-magnesite refractories ; on the elasticity (a property that is in some degree associated with the spalling tendency) of fireclay and other products ; on the permanent linear change when fireclay refractories are heated ; and on other topics.

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The British Steel Castings Research Association

By A. H. Sully, M.Sc., Ph.D., F.Inst.P., F.I.M.

Associate Director

THE evolution of the British Steel Castings Research Association from the Research and Development Division of the British Steel Founders' Association has previously been described: it became a grant-aided Research Association in April, 1954. Fifty steel foundries are full members of the Association and the tonnage of steel castings made by member firms is about 80% of the total tonnage made by the steel founding industry in this country.

Although, in the past, the Association has been able to sustain a substantial volume of investigational work on behalf of the industry which it represents, the facilities for experimental work available to the permanent staff have been limited to small metallurgical laboratories at the Association's temporary headquarters at Broomgrove Lodge, Sheffield, and to those provided by the generous collaboration of member firms. In order to provide facilities more in line with the research needs of the industry, the Association has proceeded with its plan for the erection of a fully equipped research station. Although the project has suffered some delay, due to the difficulty of finding an adequate site in the Sheffield area, this has now been successfully accomplished. Detailed plans have been made and building operations will commence in the near future. It is hoped that the station will be ready for occupation in the summer of 1956.

The station will consist of an experimental foundry, chemical, metallurgical and physics laboratories, a test house, machine shop and dust research station. A separate block will house the administrative offices and the library and information services. Steel melting furnaces of up to 5 cwt. capacity are to be installed, together with adequate facilities for sand preparation, moulding and the dressing of castings. The Association will thus be provided with experimental facilities to pursue its main lines of experimental work; these may be grouped roughly into five main fields of activity, *viz.*:—Industrial Health, Plant Engineering, Moulding Materials, Foundry Practice and General Metallurgy. Although the new station will enable the Association's programme of research to proceed with enhanced effectiveness, considerable importance will still be attached to the facilities provided by members for work in their foundries. The use of these facilities for practical trials under normal industrial conditions constitutes a most important step in the successful application in the industry of the results of research which is inevitably carried out on a smaller scale and with closer laboratory control than can reasonably be expected in industrial practice.

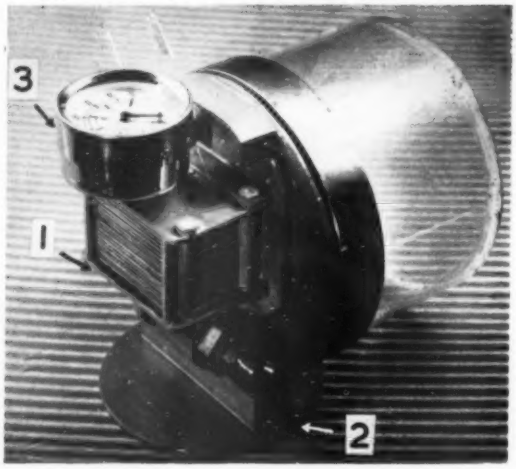
The Association attaches considerable importance to the activities of its committees. The research programme is determined by its Research Committee, which is appointed by the Council of the Association, and meets at six-monthly intervals to review the programme of research and to receive reports of progress. The Director and staff are assisted in the prosecution of the work by five Advisory Committees, corresponding to the five main lines of enquiry listed above. In preparation for the increased research activity which will result from the completion of the new laboratories, these Committees have recently been re-constituted. They comprise experts drawn both from member firms and from outside the industry, and, apart from the valuable advice which they give to the Association's investigators, every attempt is made to include representatives from as many member firms as possible on one or other of the Committees, so that they form a valuable channel of communication between the Association and the industry.

The maintenance of close contacts between the staff of the Association and the steel founding industry which it serves is considered to be of great importance. During the past year an increased number of visits has been made by B.S.C.R.A. staff to member firms, to give advice on problems which they have encountered, or to recommend procedures, particularly in the fields of sand control, steelmaking and dust suppression. The close contact between the Association and its members is also shown by a steadily increasing utilisation by members of the facilities provided by the Information and Library Services.

The application of research results and knowledge of new techniques is fostered by holding periodic conferences and discussion groups. The former are usually held on a national basis. They are open to all members of the Association and deal with problems of major importance to the whole industry. A typical example is the conference which the Association organised this month at York on the subject of "Dust Control and Foundry Ventilation." Discussion groups are more commonly held on a regional basis, and are planned to provide facilities for a free exchange of opinion between the Association and its members, or between the members themselves, on a new process or a common problem. Being held in a number of centres, and being usually of short duration, they provide an opportunity for a number of representatives from each member firm to attend.

The Association continues to maintain continuous liaison with other research associations on matters of common interest, and has friendly contacts with comparable organisations serving the steel founding industries in other countries. During the present year visits have been made, or are projected, by the Association's staff to research laboratories and steel foundries in several countries in Europe, and in the U.S.A. and Canada.

The research and other activities outlined above continue to be supplemented by research of a more basic nature sponsored in University Departments. During the past year, funds have been made available for work in the Refractories Department of Sheffield University



(1) ELUTRIATOR TO REMOVE COARSE DUST PARTICLES.
(2) AIR EJECTOR TO PROVIDE AIR FLOW THROUGH FILTER.
(3) PRESSURE GAUGE (TO DETERMINE PRESSURE DROP ACROSS CRITICAL FLOW ORIFICE).

Fig. 1.—Prototype dust sampling equipment.

under Dr. J. White, in the Metallurgy Department of Cambridge University under Dr. T. P. Hoar, and in the Chemistry Department of Reading University under Dr. P. F. Holt. The following account of some of the researches undertaken by the Association is by no means comprehensive and describes only some lines of work in which substantial progress has been made.

Industrial Health

The work of the B.S.C.R.A. in the field of industrial health is carried out in close collaboration with the British Steel Founders' Association, who make a substantial contribution to the general funds of the Association, supplementing the subscriptions made by the members. Work on this subject has proceeded under three main heads :

(1) the sampling of airborne dust concentrations ;
(2) the suppression of dust during grinding and other dressing operations ; and
(3) investigations into the cause of silicosis.

The Sampling of Airborne Dust Concentrations

Although it is believed that the major cause of silicosis is the inhalation of finely divided silica particles, especially those with freshly fractured surfaces, there is no method available by which the toxicity of a dust sample can be directly assessed. Because of the lack of such an assessment of the critical quantity, it is necessary to regard all dust as dangerous, although in fact a large proportion of such dust in steel dressing shops will consist of steel and other materials which are not active agents in promoting silicosis. The pathogenic action of silica dust is now reliably related to the solubility of such dust in the cells of the lung. The solubility in turn is directly related to the surface area of the particles, so that a method of dust sampling which depends upon a determination of the surface area of the dust is more relevant to the health hazard caused by the dust than more conventional methods based on particle count or mass concentration. The surface area may be assessed by the light scattering produced by the dust when it is suspended in a suitable fluid, and this nephelometric method has been developed by Dr. P. F. Holt at Reading University. The Association's staff has collaborated in the development of a dust sampling instrument designed to take long term samples for assessment by this method. This instrument is shown in Fig. 1 ; it is operated by compressed air and incorporates an elutriator, which is designed to simulate the function of the upper respiratory tract, which retains coarse dust particles before they reach the lung. The sample, which

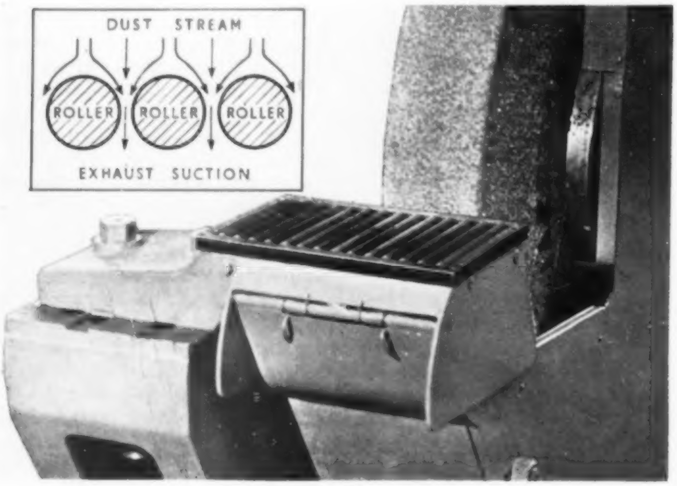


Fig. 3.

Fig. 2.

Fig. 4.

Fig. 2.—Dust cloud escaping at side of stand grinding machine during grinding at a point on the wheel some distance above the perforated work rest.

Fig. 3.—Roller type work rest designed by the Association.

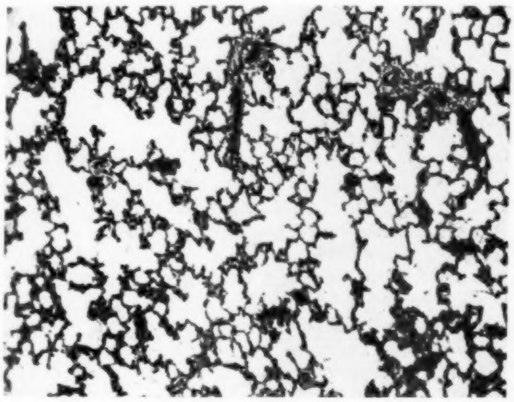
Fig. 4.—Good control of primary dust stream with roller type work rest grinding under same conditions as Fig. 2.

is collected on an organic base filter after passage through the elutriator, thus includes only the finer dust particles which would normally reach the alveola of the lung. The filter is subsequently dissolved in acetone, leaving the fine dust particles in suspension to be assessed by nephelometric or absorptiometric methods.

This method promises to be speedier than other methods of dust assessment, and work is continuing in the hope that it will enable members to carry out regular dust counts in their works with relatively simple apparatus.

The Suppression of Dust during Dressing Operations

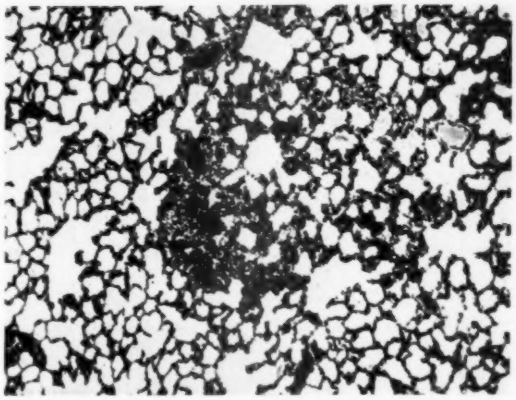
The work of the Association on the suppression of dust generated during grinding with pedestal and swing frame grinding machines has been mentioned in surveys published in earlier years. Work has continued to improve the exhaust systems and to maintain the dust control efficiency of the systems under a variety of operating conditions, and negotiations have been satisfactorily concluded for the manufacture of grinding machines incorporating the Association's dust control devices.



Courtesy of Dr. P. F. Holt

Fig. 5.—Section of lung tissue from a normal rat. The air vessels are enclosed by very thin tissue which is easily extensible. × 60

One development illustrated by Figs. 2–4 relates to a new improvement which has been made to the exhaust system for pedestal grinding machines. The original system proposed by the Association incorporated an integral exhaust drawing air into the specially designed cowl of the machine and through a perforated work rest. It was found, however, that it was common practice in some foundries to carry out grinding at a point on the wheel at some distance above the work rest. Under these conditions some of the primary dust stream was either deflected by the work rest or left the point of grinding at angles such that it did not come within the zone of influence of the exhaust suction operating through the perforations of the work rest. The dust escaping to the side of the machine is shown in Fig. 2. A roller type of work rest has now been designed (Fig. 3) which satisfactorily controls the dust generated by grinding high up on the wheel (Fig. 4). This has been successfully tested in practice. It not only gives improved dust control but rotation of the rollers ensures that the apertures are self-cleaning and do not become clogged, as may easily happen with a work rest with circular perforations.

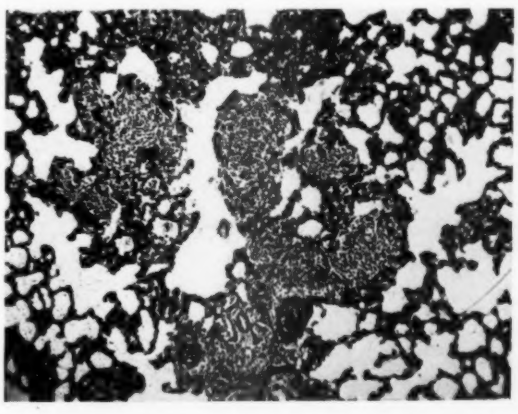


Courtesy of Dr. P. F. Holt

Fig. 6.—A section of lung tissue from a rat which has inhaled carborundum. Black dust is seen packed in the tissue, completely filling some air spaces, but the tissue has suffered little damage. × 60

In conjunction with members of its Plant Engineering Advisory Committee, the Association has obtained detailed information upon a large number of different types of dust collecting systems, some of which are novel to steel foundry applications. The accumulation of such data is a logical preliminary to a comparative study of the efficiency of such equipment, and the problem of devising an acceptable method of assessing efficiency is now under active consideration.

It should also be mentioned that other of the Association's researches have an important, if more indirect, bearing on the subject of industrial health. The problem of minimising sand adherence to steel castings, which is under investigation at Cambridge University, is of considerable importance in this respect, as well as in reducing the cost of dressing operations. A reduction in the amount of burnt-on sand will automatically reduce the amount of silica dust generated during grinding.



Courtesy of Dr. P. F. Holt

Fig. 7.—A section of lung tissue from a rat which has inhaled silica dust. In parts the normal structure is completely replaced by a dense mass of fibres and everywhere the walls of the air vessels are thickened. × 60

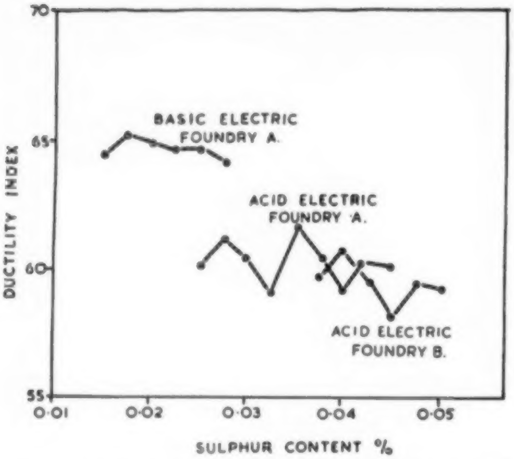


Fig. 8.—Variation of "ductility index" with sulphur content for basic and acid electric steels.

The Cause of Silicosis

Fundamental research at Reading University under the supervision of Dr. P. F. Holt has continued, and has led to an insight into the manner in which silica dust promotes silicosis. The active agent is silicic acid produced by the solution of finely divided silica within the cells of the lung. Silicotic lesions are fibrous tissue similar to normal fibrous tissue, but its formation in the lung which when healthy has a sponge-like open structure hinders its normal functioning. Fig. 5 shows normal lung tissue, Fig. 6 shows tissue from the lung of a rat which had inhaled carborundum dust, and which does not include silicotic lesions, and Fig. 7 shows tissue from the lung of a rat with marked development of fibrous tissue after the prolonged inhalation of silica dust. The growth and stability of normal fibrous tissue is due to the stabilising action of certain naturally secreted chemicals, the mucopolysaccharides. By observations on fibrous tissue, and by measurements of the interaction between silicic acid and protein, Dr. Holt and his collaborators have shown that silicic acid under certain conditions can promote the formation of fibrous tissue and stabilise it in the same way as the mucopolysaccharides. The growing understanding of the causes of the disease strengthens the hope that the continuance of work of this nature will ultimately lead to an effective method of prophylaxis.

Mould and Core Bonding Agents

Most British steel foundries using synthetic sand mixes for moulding use imported bentonitic clays as bonding agents. In an effort to replace these imported bentonites, the Association has examined thirty-six British kaolinitic clays, including ball clays, china clays and siliceous fire clays. The cost of these clays is much lower than that of bentonite. In general their bonding properties are lower than those of the best bentonites, but it has been shown that some can be used with success to replace up to 50% of the bentonite in synthetic sand mixes without significant loss of dry strength. Preliminary work confirmed by practical trials in the foundry of a member firm, has indicated that these mixtures give a casting "strip" as good as that obtained with the normal bentonite bonded sand, and that the foundry "life" may be better.

Tensile Properties of Acid and Basic Steels

It is commonly considered that steels produced in basic electric arc furnaces are superior to steels produced in acid lined furnaces or converters. This difference in so-called "quality" has been the subject of investigation in order to determine whether it could be attributed solely to differences in sulphur and phosphorus contents, or whether other factors were involved. An analysis has been carried out of tensile test results on basic steels and on acid electric steels made by two members of the Association. The results are illustrated by Figs. 8 and 9, in which they are expressed as the "ductility index" of the steel plotted against the sulphur and phosphorus levels respectively. (The ductility index is a somewhat hypothetical measure of quality in which an attempt is made to allow for differences in ultimate tensile strength between samples. It is used in order to facilitate comparison between steels of different carbon content and consequently different tensile level). The steels used for this investigation contained 0·18–0·35% carbon and comparison on any other basis would have been difficult. Tests were made on specimens in both the annealed and normalised conditions. The actual tensile ductility of the steels made in acid furnaces was only on average 85% of that of similar steels produced in the basic electric furnace. Figs. 8 and 9 make it clear that this difference cannot be attributed to differences in sulphur or phosphorus content, and that the difference in "quality," which is real, must involve process variables which are still incompletely understood.

It must be understood that this interesting result does not imply that normal restrictions on sulphur and phosphorus contents are less important for basic than for acid steels. Tensile ductility is not a complete index of quality and an assessment on the basis of impact value would show that the best results can only be obtained by maintaining the sulphur content at a low value. A danger exists also that deoxidation techniques would result in low values of tensile ductility if the sulphur content were high.

Microporosity in Steel Castings

Earlier investigations of the mechanism of freezing of steel castings conducted by the Association have

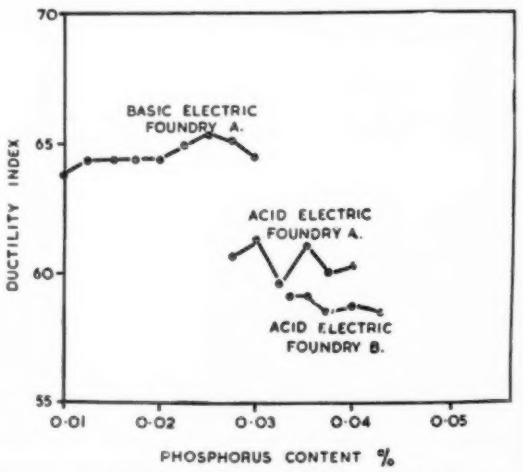


Fig. 9.—Variation of "ductility index" with phosphorus content for basic and acid electric steels.

demonstrated that regions of columnar crystal growth, normally found at the outside surface of castings, are usually sound and have high tensile ductility. Regions of equiaxial and nuclear crystals, on the other hand, exhibit low and variable ductility in tensile tests. Radiographic examination of thin sections cut from castings has revealed that this is attributable to finely dispersed interdendritic cavities, present to some extent throughout the central regions of the castings. The quantitative assessment of this microporosity and a measurement of its effect upon the impact resistance, ductility and endurance ratio of castings constitutes an important project on the programme of the Association's metallurgical staff. Refined measurements of density afford some promise as a method of assessment, but considerable accuracy of measurement is required. It has been found that a significant effect on tensile ductility is produced by a degree of microporosity which corresponds to a density only 0·07% lower than that of sound metal. The study of the formation of microporosity represents an extension of the Association's earlier work on the mechanism of freezing, and requires that attention be paid to the last stages of solidification. An attempt is also being made to determine to what extent microporosity is due to finely dispersed shrinkage porosity and to gas evolution from the metal, respectively. That the latter plays an important part is clearly shown by experiments which have been made under vacuum. The central regions of castings solidified under vacuum exhibit appreciably higher ductility than corresponding regions of castings solidified in air.

The British Cast-Iron Research Association

By Dr. J. G. Pearce, O.B.E.

Director

THE year which closed at the end of June, 1955, was a momentous one for the B.C.I.R.A., as it was the first year of a new quinquennium for which arrangements have been made with the industry through the Joint Iron Council, and with the Department of Scientific and Industrial Research, for an expanded programme. These plans are in active progress.

During the year 22 reports of original research work carried out in the laboratories were published in the *Journal of Research and Development*, and figures given in brackets below refer to the numbers of the reports concerned. A similar number of lectures was given to a number of bodies at home and abroad by the staff of the Association, and a further 20 reports and papers by the staff to other scientific bodies were published.

Of two Conferences held, one on the Research Programme in November, 1954, and the second on Foundry Ventilation and Dust Control, the latter provides the key to the work of the year. This Conference attracted the largest number of members of the dozen or more conferences staged by the Association during the last seven years, and considerably more than the first Conference on the same subject which was held in 1951. One reason for this lies in the issue of the Iron and Steel Foundry Regulations, a number of which took effect in January, 1954, but the ventilation and dust-control clauses of which become operative at the beginning of 1956. The April Conference was designed to present the work done and conclusions reached during the intervening period in order to assist member-firms and ventilating engineers in carrying the requirements of the regulations into effect in the most economical manner.

The Conference was opened by Sir George Barnett, H.M. Chief Inspector of Factories, in a comprehensive talk on Health and Safety in the Foundry Industry, and fifteen papers were presented, mostly by members of the staff, dealing with such problems as dust control in the cleaning of castings; the collection of cupola dust (402); high-pressure cleaning and high-pressure shot

Fig. 1.—Dust control on pedestal grinders.

Fig. 2.—Dust control for the swing frame grinder.

blasting of castings; and sand cooling (387). A statement of the requirements for efficient dust suppression at the foundry knock-out was presented on behalf of the Association's Foundry Atmospheres Committee, and two papers dealt with the results of an elaborate experimental programme on the same subject. It is proposed to issue all the papers presented in one cover and this publication is now in the press.

Fig. 1 illustrates an industrial installation of the Dusgard arrangement for withdrawing dust created by the fettling of castings by pedestal grinders. The slots in the shield above the wheel create by suction an air curtain which prevents dust rising to the operator's breathing zone. Fig. 2 illustrates the design of a booth for controlling dust from swing frame grinder operations (386), whilst Fig. 3 shows an ordinary de-coring bar or pick used for removing heavy cores in large castings. The latter device is mounted with a collar designed with jets fed by a town's water supply, controlled by a simple valve, enabling a spray to be thrown on the core in advance of the pick and thereby preventing a dust cloud. All these designs are due to the Association's Foundry Atmospheres Team.

Fig. 3.—De-coring bar with water spray.

Demand has continued unabated for the four-day courses on sand control and testing, and by the end of 1955 thirty such courses will have been held, dealing with over 330 members' representatives. This work, together with that on foundry atmospheres, constitutes part of the activities of the Development Department, which has otherwise continued on the lines previously reported.

The Operational Team has paid over 100 further visits to foundries, and a statistical examination of some results of visits to the first half of these has been issued (390, 391).

Research

Work carried out during the past few years on gases in cast iron was summarised by the Research Manager, Mr. H. Morrogh, in a paper to the International Foundry Congress held in London in June, 1955. With respect to gases in molten iron, work on the partitioning of nitrogen between elements such as aluminium and titanium, etc., and iron has been completed. This involves the measurement of the acid-insoluble and the acid-soluble fractions during the chemical determination of nitrogen (396). The neutralization of the effects of nitrogen by aluminium and titanium is shown to take place by the formation of acid-insoluble nitrides.

A technique has been developed for the estimation of hydrogen in cast-iron using vacuum heating. It has been established that the vacuum heating technique can be applied to the determination of hydrogen in white cast irons. Apparatus has been developed to measure both the rate of evolution and the total volume of hydrogen (397). A promising technique using "sucked" samples has been developed in connection with sampling of molten metal for hydrogen estimation. Other work has included the influence of hydrogen on chilling tendency, structure and soundness; the influence of oxygen on chilling tendency; and the influence of hydrogen on the soundness of austenitic irons.

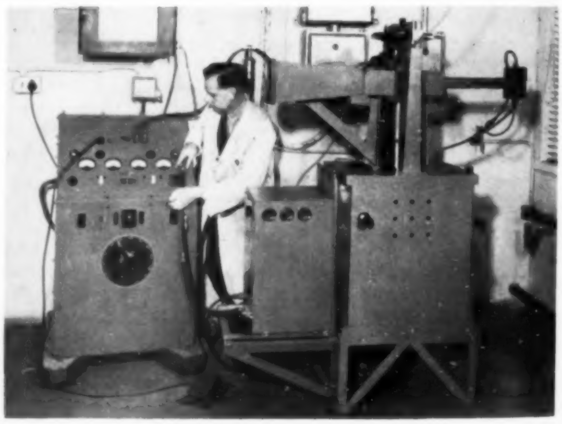


Fig. 4.—High frequency apparatus for testing moulding sands.

Results have been issued of significance to enamellers

of light castings for domestic use on the influence of melting and pouring temperatures, inoculation, moulding practice, and design variables upon sinking under bosses in thin plates (405). A study of the evolution of gases during the enamelling cycle, by heating samples in a stream of purified argon and examining the gases evolved with an infra-red gas analyser, has shown that such gases increase with storing time before treatment, and also with annealing.

Two papers (399 and 400) have described progress in the study of solidification sequences. Thermal analyses are done on test pieces to study the effect of pouring

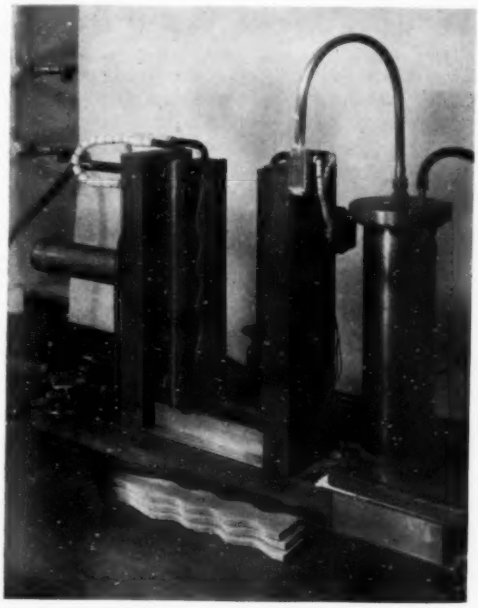


Fig. 5.—Shell moulding sand test piece in opened mould.

temperature, silicon content and inoculation, and the results are interpreted by microscopic methods. Keel type test blocks of nodular cast iron have been subjected to detailed microscopic and mechanical examination to determine porosity distribution. Work on the effect of oxygen on shrinkage defects revealed that wide variations in oxygen content failed to alter shrinkage characteristics of grey, blackheart malleable and whiteheart malleable cast iron K-bars of varying phosphorus content. A study of CO_2 process moulds shows that they compare favourably with dry sand moulds in influencing soundness of castings. Work continues on the effect of melting and pouring temperature on uninoculated irons of varying carbon and phosphorus content.

Investigation has been made of surface pinholing in nodular iron (403). It has been shown that pinholing in ordinary grey iron can be produced by small additions of aluminium to molten metal, the severity of the defect varying with the section thickness and the amount of aluminium added.

An up-to-date statement (408) on graphite formation was presented to a conference on graphitisation held at the University of Birmingham in March, 1955.

Fig. 6.—Quantometer (right) and grating spectrograph (left).

Detailed field studies are in progress to investigate the cause and possible cure of drawing in light section castings. Data collected from one foundry over 18 months are being subjected to exhaustive statistical examination.

Work has been published on the use of high-frequency apparatus for the rapid heating of sand test pieces, enabling them to be tested mechanically at very high temperatures. The apparatus is shown in Fig. 4.

A report has appeared (401) on the influence of increasing amounts of dead clay on the properties of moulding sand, revealing that an excessive build-up of dead clay can be detected by routine tests for moisture content, green strength and shatter index ; methods of controlling and neutralizing the effects of dead clay are indicated.

A preliminary report (395) has been published on a rapid method of estimating moisture content of sand by measuring its capacitance ; this method is influenced by the packing density, but is not affected by small changes in amounts of coal dust, clay or tramp iron, or by the thickness of the sand layer. To supplement the laboratory investigation, this work is being extended to obtain continuous records of the moisture content of a stream of sand in a mechanized plant. Fig. 5 shows the apparatus devised for making a sand test piece in sand for shell moulding, to enable the effects of sand type and grade, proportion of resin, temperature and other variables to be quickly assessed. Methods of testing shell moulding materials and their properties have been described (398).

Field tests continue on the cathodic protection of cast-iron ship propellers and the prolongation of anode life. Heavy duty coatings on propellers have been examined in conjunction with cathodic protection. The cathodic protection of buried cast iron pipe is also under observation.

The problem of the high phosphorus content of British foundry pig irons and other raw materials continues to be investigated (389). A special panel of co-operating members has been formed from the ironfounding industry to advise the Association on its activities in this connection.

Co-operative work to improve routine chemical analysis has been continued. The sampling of nodular

(*continued on page* 200)

The British Non-Ferrous Metals Research Association

By E. C. Mantle, M.Sc., A.I.M.

Chief Liaison Officer

THIS year the Research Association has celebrated the 25th anniversary of the founding of its own laboratories (after 10 years spent as guests elsewhere) and a short account of some of the achievements of the past research work has already appeared in an earlier issue of METALLURGIA. During the year a further extension to the laboratory accommodation has been made, bringing the total floor space up to some 43,000 square feet. Almost fifty research projects are now under way. They cover a very wide range of subjects and only a few can be dealt with in this article. These have been selected to illustrate the many ways in which the research work is helping the various sides of the industry to advance technically or to find new outlets for their products.

Much of the work a co-operative research organisation undertakes must inevitably consist of evaluating existing materials and throwing light on their behaviour in production or service. Probably no other organisations are so well fitted as the Research Associations for providing this background information. An example of this kind of work is the research being undertaken into the causes of directional properties in high-strength aluminium alloy extrusions. These materials are used for important structures such as airframes, crane jibs and so on. The extrusions have excellent strength and ductility in the longitudinal direction, the direction in which they are stressed in service, but the properties, especially the ductility, are lower in the transverse direction. Better ductility in this direction, if it could be attained without sacrifice of longitudinal properties, would offer advantages in providing a greater margin of safety to accommodate indeterminate stresses arising, for example, around rivet holes or in aligning the assembly. The alloys have a complex constitution with a large proportion of intermetallic particles, and the initial objective of the research is to determine just what controls the directionality of properties. Is it, for example, the size and distribution of the intermetallics, could it be oxide inclusions, or is it texture associated with the extrusion process? In its initial stages, this research work has been concerned with determining the extent of the directionality in a large number of typical extrusions, and experiments are being made to see whether "pure alloys" more or less free from intermetallic inclusions exhibit the same directional properties.

Rolling thin copper strip by pouring copper powder between a pair of rotating rolls.

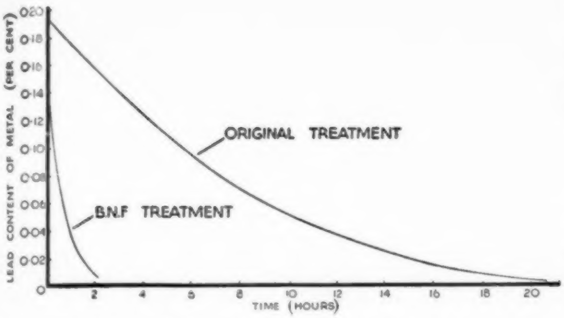
Rolling Metal Powders

A direct contrast with the type of work described above is the research being carried out into the rolling of metal powders. The object here is to evaluate a comparatively new process that has not so far been exploited on a commercial scale. The process consists in compacting metal powders into strip or wire by direct rolling, without the use of any pre-pressing or pre-sintering process.

At present, copper powder, in common with most metal powders, is expensive compared with the bulk metal, and although this process might have limited uses for the production of specialal loys, it can only become economically attractive with the availability of bulk supplies of cheap copper powder. The research is really being undertaken in anticipation of the eventual expansion of the chemical reduction methods of processing scrap and ores now being worked on a pilot scale in America. These produce the metal in powder form and if the powder is cheap enough, roll bonding of such powder might become an important industrial operation.

Removing Lead From Copper

A very successful process has been developed within the last twelve months for removing lead from copper. This work was undertaken to meet a demand for a better method for removing the last traces of lead during the fire refining of secondary copper. The lead can be removed comparatively easily by oxidation and slagging with sand until the 0·1% level is reached, but to reach the 0·005% level needed for many purposes meant repeated treatments, adding as much as 24 hours to the refining cycle. Copper losses in the slags would become proportionately high and wear on the furnace refractories severe. Using the process developed by the



Comparison of the rates of removal of lead from copper by the original and B.N.F. treatments (works trials).

Association, the same reduction in lead content can be obtained in such a short time that the treatment can be completed within the space of the usual 24 hour fire refining cycle, with a consequent saving of fuel, labour and refractories. At present the cost of the agent used is comparatively high, although the indications are that it will be possible to cut this by at least half by using an alternative source, but in any case the savings in copper losses alone easily offset the cost of the material. A number of successful industrial demonstrations of the process have been made and it is now in regular use at some refineries. There is a possibility that a similar process could be used to remove lead from copper-base alloys such as the tin bronzes.

New Uses for Materials

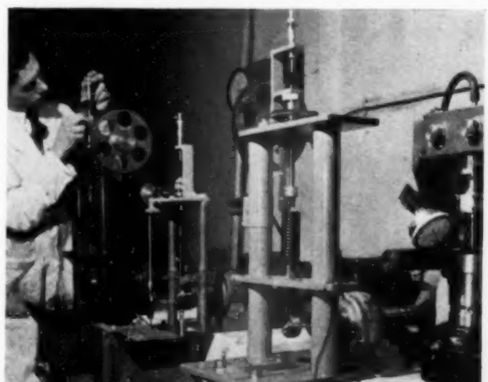
To fulfil its functions properly a research organisation has not only to assist in the technical advancement of its industry, but also in the expansion of the use of the industry's products. Several of the Association's researches are directed to this end. For example, an investigation is being made to determine to what extent it might be possible to use aluminium alloys for handling ordinary supply waters. In most waters in this country, aluminium and its alloys undergo pitting corrosion under conditions of stagnation and would be unsuitable for use for plumbing installations and the like, though, of course, they are used almost universally and are perfectly satisfactory as cooking utensils where, however, the conditions of service are somewhat different. Laboratory work has shown, however, that by suitable modifications of the surface, pitting corrosion can be prevented, even under conditions which would otherwise be very aggressive. So encouraging have the laboratory experiments been that plans are afoot for the installation of some complete plumbing systems where extensive use will be made of aluminium alloys protected in this way.

Another research is concerned with finding a new finish for zinc base die-castings. When the latter have to be exposed to the atmosphere, or when they are needed for decorative purposes, they are usually either electroplated or painted. An alternative finish might lead to the more extensive use of zinc alloys, and the Association has been asked if it would look into the possibility of developing a method of finishing zinc alloys analogous to the anodic treatment used for aluminium alloys. What is required is a surface treatment which would produce a hard and durable film with an attractive appearance or capable of taking attractive dyes. At the outset this seemed a rather hopeless quest, because of the marked difference in the nature of the oxide film formed on zinc and that formed on aluminium, but already some encouraging results have been obtained from the small-scale experiments which have been carried out.

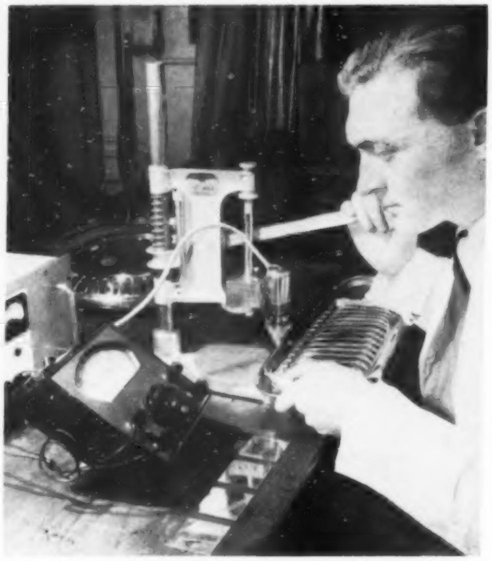
Materials for Gas Turbines

A number of the Association's researches are connected with the development of the gas turbine and turbo-jet engines. Although no work has been carried out on the alloys used for the actual high temperature parts of these engines, much has been done in connection with materials to be used in the compressors. Studies of the creep and fatigue properties of aluminium alloys used for the low temperature end of the compressors were carried out some time ago, and more recently similar data have been collected for aluminium bronzes of the D.T.D. 197A type used for forging compressor blades to operate at higher temperatures. The Association has also a Ministry of Supply contract for the development of titanium alloys with good mechanical properties at elevated temperatures, and a considerable effort is being put into their development and the evaluation of their mechanical properties. This work has given the staff of the Association invaluable experience in the handling of this new addition to the range of non-ferrous metals.

The large gas turbines being developed for electrical power generation and marine propulsion depend for their efficiency on the recovery of the heat from the exhaust gases, and there is a problem in connection with the development of heat exchangers suitable for operating at temperatures of the order of 500° C. and able to handle exhaust gases containing substantial quantities of sulphur dioxide. Ordinary mild steel has so far proved satisfactory at temperatures up to about 400° C., but little is known about its behaviour at higher temperatures under these corrosive conditions. An investigation has been made of the performance of various copper-base



Machines for the accelerated assessment of fatigue resistance: the centre one is suitable for lead alloys and the others for stronger metals.



B.N.F. coating gauge for the measurement of the thickness of electroplated coatings by a thermo-electric method.

alloys which might find uses as a replacement for mild steel should operating conditions become more severe. In the first place an evaluation was made of the mechanical properties of various aluminium bronzes and complex cupro-nickels at temperatures of the order of 500° C., and later work has been concerned with assessing the resistance of these alloys to corrosion. For this purpose equipment has been built in the laboratories simulating the conditions encountered in practice, and this has been used as a sorting test which has been followed by field trials in actual heat exchangers on promising materials.

Another aspect of the Association's work which touches on the development of the gas turbine is an investigation into high temperature brazing. There are two main difficulties in brazing high temperature steels and other high temperature alloys for applications of this kind. The first is the fact that the brazing material must itself be strong at temperatures of the order of 1,000° C. or more, but at the same time must have a melting point appreciably below those of the materials to which it is being applied. Secondly, these high temperature materials all form refractory oxides demanding special techniques to enable the brazing metal to wet the joint satisfactorily. The Association's work in this field is concerned with determining the factors which affect the flow of the brazing material, how the design of the joint is related to the ease with which it can be consistently filled, and how the strength of well-filled joints is related to the composition of the brazing alloy and to the extent of alloying and interdiffusion which occurs with the basis metal.

New Techniques

A number of new laboratory techniques have been developed recently, perhaps the most important of which is a method for determining in a short time the resistance of a material to fatigue. This test was originally developed to fulfil the need for a routine fatigue test for certain types of alloys. Whereas, following the conventional method of preparing a fatigue endurance curve, it takes up to eight weeks to determine the endurance limit of an alloy, using one fatigue machine, the rapid method developed in the laboratories enables it to be arrived at within about 24 hours. The machine used follows the principle of a progressive loading test developed by Prot, but the test is applied in a fundamentally different way. The specimen is rotated at 3,000 r.p.m., loaded as a simple cantilever by means of a spring. At the commencement of a test zero load is applied, and by gradually extending the spring during the course of the test the load on the specimen is increased until it finally fractures. This is arranged to take place in a period ranging from 5 or 6 hours up to 24 hours according to the strength of the material. It has been found that for lead alloys, copper alloys and steels there is a direct relation between the " dynamic breaking load " as determined by this test and the endurance limit of the material determined in the conventional way. Thus it is possible to use the machine either for routine testing of batches of material or as a test for rapid assessment of the fatigue resistance of new alloys. Another interesting potential use is for quickly estimating notch sensitivity or the notch effect in a particular type of joint, etc; preliminary investigations indicate that the machine could do this just as efficiently as the time-consuming endurance tests.

New techniques have also been developed in the analytical laboratory, where the emphasis is being placed more and more on the use of physico-chemical methods. Considerable use is now being made of spectrophotometry, both for ordinary metallurgical analysis and, more especially, in connection with the development of methods for the control of the organic constituents in electroplating solutions. For this latter purpose an ultra-violet spectrophotometer is employed.

Ion-exchange resins are also finding a considerable place in the analytical work. These resins are of two types: those which will remove anions from solutions and those removing cations. Both types have their uses in metallurgical analysis. For example, those which will quantitatively remove cations from solutions are frequently employed in the laboratories to remove coloured metallic ions which would otherwise interfere with the end points in titrations. A large ion-exchange column containing a mixed bed of anion and cation exchange resins has been constructed for supplying the laboratories with " pure " water for analysis. Tap water passes through the column and the anion exchange resins remove the acid radicles, while the cation resins remove the metals. Eighty gallons of water can be purified between regenerations and the cost of operation is considerably lower than electric stills. Ion-exchange resins have also been applied to the analysis of electroplating solutions, permitting time to be saved in many instances and often resulting in greater accuracy.

An important contribution to control and inspection in the electroplating industry is the coatings gauge developed for measurement of the thickness of electroplated coatings. This fulfils a long-standing need for a non-destructive test, and is a fitting successor to the B.N.F. jet test, which has for so long been the standard routine method of determining the thickness of electroplated coatings. The new coatings gauge works on an entirely novel principle depending on a thermo-electric effect. Briefly, it consists of an electrically heated probe which is applied to the surface of the electroplate between two adjacent probes which are not heated. Heat from the

(*continued on page* 184)

The Production Engineering Research Association of Great Britain

By Dr. D. F. Galloway, Wh.Sch.

Director of the Association.

DURING the past two years the Association has continued to expand and the total membership now exceeds 500 firms, representing all sections of the engineering industry. Demonstrations, open days, liaison visits, special training courses, and other educational activities for a wide range of production personnel have stimulated an increasing awareness of the economic advantages to be gained by application of PERA's research results and recommendations for improved production techniques.

Mobile Demonstration Unit

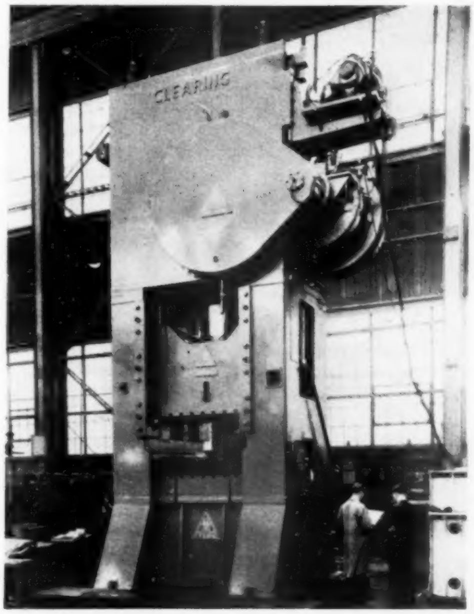
An important addition to the facilities for these educational activities is the PERA mobile demonstration unit, which was put into service towards the end of 1954 after being on show at the Production Exhibition at Olympia and the Scottish Industries Exhibition in Glasgow. This unit tours engineering firms throughout the country presenting films, illustrated talks, and demonstrations on production techniques recommended by PERA. Its construction and initial operation were made possible by Conditional Aid from the United States of America.

Visits by the unit are mainly for the benefit of shop floor personnel in firms where the management require the recommendations of PERA to be adopted with the minimum delay and with the co-operation of foremen, chargehands, operators, etc. Subjects of the alternative sessions available in the unit include blanking and bending of sheet materials; deep drawing; impact extrusion; machine tool selection and maintenance; efficient cutting tool utilisation; and recent developments in the machining of metals. A series of special films made by PERA for use in the mobile unit includes illustrations of the applications of automation to both large and small scale production.

Research Programme

Equipment

During 1954, delivery of research equipment made available through the Foreign Operations Administration was completed, bringing the total value of such equipment received to about £250,000. The last and largest item, which was received in December, 1954, was a 1,000-ton impact extrusion press. Other machines which have been received during the past two years include a 300-ton double-action hydraulic press, a cylindrical die thread rolling machine, a 1,000-ton hydraulic hobbing press, and a powder metallurgy press. Some valuable items of testing equipment have also been obtained through F.O.A. during the past two years. These include an automatic recording titrator, a grinding wheel grading comparator, a panoramic "sonic" analyser, and a bench polaroscope. The facilities for research have been further extended by the purchase of



A 1,000-ton press as illustrated above was recently received by PERA through F.O.A. for research on the impact extrusion of steel.

additional testing equipment, including a tensile testing machine, a Vickers projection microscope, and gamma-ray flaw detection equipment.

Grinding

Research reports have been issued on wheel dressing techniques; the effects of workspeed and infeed on cylindrical grinding performance; and a comparison between the conventional method of applying cutting fluid and the method of feeding the fluid radially through the body of the grinding wheel.

Turning

Investigations which have been recently completed include an assessment of the "Hi-Jet" system of cutting oil application, based on tests carried out at PERA; an investigation into the effects of tool surface finish on tool life and workpiece surface finish; and tests using liquid carbon dioxide as a cutting fluid.

Drilling and Tapping

Reports have been issued on investigations to determine the best methods of drilling and tapping titanium alloy Ti 150A. Tool grinding specifications for drilling cast iron and low carbon steel were the subjects of other drilling investigations, while current tapping research

includes investigations into the relative performances of nominally similar taps, and the influence of nitriding on tap life.

Blanking and Piercing

Following successful researches on the production of high quality sheared edges when blanking non-ferrous metals such as aluminium and copper, investigations are continuing with a view to providing similar recommendations for the blanking of steel components. Considerable interest is being shown in these investigations, and many firms are already obtaining substantial savings in production costs by applying the recommendations arising from research so far carried out.

To assist firms in economically allocating press capacity for blanking operations, a report has been issued containing information obtained by research at PERA for determining the relationship between blanking force and area in shear for a wide range of materials in various thicknesses. The report demonstrates the unreliability of estimating blanking forces by multiplying the area in shear by the ultimate tensile strength of the material concerned. Other research into blanking and piercing at present in progress includes an investigation to determine the relative life of punches manufactured from various materials, when blanking a number of different materials.

Impact Extrusion

Investigations into the tooling and operating conditions required for impact extrusion in various materials have been extended. A report has been issued on the impact extrusion of copper, and a preliminary investigation has been completed on the impact extrusion of steel. Other materials being investigated include aluminium, zinc, and duralumin. A more extensive investigation into the impact extrusion process will take place when the new 1,000-ton impact extrusion press is in operation.

Deep Drawing

A report on the comparative performance of different drawing lubricants for mild steel showed the importance of correct lubricant selection for obtaining drawn cups of maximum depth. Other materials covered by the deep drawing investigation include brass, Nimonic 75, and aluminium alloy. Work is also being carried out to determine the effect of punch radius and die radius on the depth of cup it is possible to produce by deep drawing.

Machine Tool Investigations

A recent investigation into the elements of machine tools included a study of the performance of angular contact bearings such as those used in lathe headstocks, internal grinding spindles, etc. Reasons for inconsistencies in performance between nominally similar bearings were determined. The features of a bearing which contribute to noise and vibration were investigated on an anderometer, which measures high, medium, and low frequency radial movements between the inner and outer races at a bearing speed of 1,800 r.p.m.

The protection of machine tool slideways is the subject of a report on the various methods of preventing attack by abrasion, corrosion and other causes. An extensive research programme which has involved the development of a special testing machine and new measuring techniques is yielding much-needed information on the performance of sliding surfaces, including plastic, ground cast iron, and scraped cast iron slideways.

The provision of information on the performance to be expected from machine tools, together with notes on the design and use of these machines, has continued. Reports have already been issued on centre-lathes, radial drilling machines, and horizontal milling machines, and a report on cylindrical grinding machines is shortly to be issued.

De-burring

Three reports forming a practical guide to the solution of de-burring difficulties have been issued. The existing reports, which refer to abrasive blasting practice, methods of manual and chemical burr removal, and methods of preventing the formation of burrs during machining, are based, not only on recently published information but, more important, on direct observations

Among the demonstrations during PERA Open Days this year was flow turning, as shown here.

A view in the Pressing Section at PERA

PERA Library which has recently been extended.

made in leading factories manufacturing a wide range of products. Other reports are shortly to be issued on de-burring with power tools, and de-burring by barrel tumbling. It is anticipated that the scope of the investigations will subsequently be extended to include information on the de-burring of metal pressings, forgings, castings, plastic mouldings, and die castings. If necessary, practical work will be carried out to establish techniques which may not have been already developed in industry.

Other Researches

Subjects of some of the other investigations recently completed or at present in progress include tests on experimental aqueous cutting fluids; the dry cleaning of ferrous wire; the effects of reamer shape and cutting conditions on the quality of hole produced; high speed hobbing techniques; and a study of the factors affecting the success of thread rolling operations.

Information Services

Technical Enquiry Service

Substantial savings in production costs are being achieved by many firms who regularly request assistance through the Technical Enquiry Service. When necessary PERA is prepared to send an engineer down to the works concerned to make a special study of the problem. Solutions to many of the problems lie within the combined experience of the enquiry engineers, but the replies that have already been given to several thousand individual production problems constitute a vast source of reference for dealing with new problems as they arise. If necessary, however, the resources of the Research Department and PERA Library, as well as external sources in Britain and abroad, are brought to bear on any particularly difficult problems.

Nearly 2,000 problems a year, embracing a wide range of production engineering subjects from the raw material stage to the packing and despatch of the finished product, are dealt with by the Technical Enquiry Service. Although many of the enquiries concern everyday processes, examples of more specialised problems recently dealt with include the automatic high speed feeding of taper pins in uniform orientation; the relationship between geometry of keys and the note produced on a toy drummer; the deep drawing of conical pressings; and the corrosion of electrical instruments under tropical conditions. Other enquirers have sought information on techniques which are coming into greater prominence, such as the use of radio-isotopes; punched-tape control of machine tools; etc.

The anderometer used in PERA investigations into angular contact ball bearings. Bearings are run at 1,800 r.p.m. and readings of radial micro-irregularities are taken in three frequency bands corresponding to the most typical bearing imperfections.

PERA Bulletin

Large savings in time at members' factories are being achieved through the bulletin and photocopy service. Abstracts of about 500 of the most significant production engineering articles in the technical press are grouped and classified for easy reference in the bulletin each month. Full copies of any of the articles are then promptly supplied upon request. About 400 journals published in Britain and abroad are covered by the bulletin, which now circulates to about 15,000 persons in industry.

This service is useful to all those executives and other personnel who would otherwise need to look through large numbers of journals each month in order to keep abreast of current developments.

Member-Liaison

Visits to members' factories by PERA liaison engineers have proved to be of considerable value in securing effective utilisation of all PERA services, and in promoting higher efficiency in individual firms. Liaison visits are made regularly to ensure that the production personnel concerned are fully aware of the way in which the lastest research results may be applied, and also to check that satisfaction is being derived from the research and information services as a whole.

Demonstration Days at PERA

Special exhibitions are held periodically at the Association's headquarters in Melton Mowbray to demonstrate the practical application of PERA researches and other developments in the field of produc-

Mobile demonstration unit which has visited about 220 firms during its first year of operation to give practical demonstrations, lectures, films, etc., relating to the latest production developments.

tion engineering. Recent exhibits have included flow turning, spark machining, friction sawing, finish blanking, and electro polishing, in addition to the more common production processes. The Open Days held during 1954 were attended by about 1,250 visitors from industry.

Special Courses

Courses at PERA of two days duration on subjects such as tool grinding and machine tool maintenance are arranged at the request of individual member-firms. The course on tool grinding is especially popular it includes instruction on the various drill point grinding machines in PERA laboratories, and in the use of drill point inspection equipment. The necessity for maintaining accurate drill grinding is stressed during the course, and the effects of inaccurate grinding, such as high relative lip height are fully explained. Instruction on the grinding of high speed steel and carbide lathe tools covers the preparation of tools prior to grinding, rough and finish grinding, and the use of the radius grinding attachment. Instruction is also given in the use of a tool angle protractor for tool measurement.

PERA Student Scheme

Twenty young engineers from member-firms have attended the six-month courses held during the past two years. The object of these courses is to develop in the student a progressive outlook towards production engineering through working with PERA research teams and attending lectures on the wider aspects of production engineering research, and by visiting selected factories.

Library Services

A valuable store of production engineering literature is now contained in the Association's Library, which is in constant use by the staff and member-firms. A considerable quantity of books and periodicals on current American production engineering practice has been received from the United States through the Foreign Operations Administration. An indication of the scale of use made of PERA Library is given by the fact that external loans are made at a rate of about 7,000 per annum (excluding photocopies) and that 2,500 items of literature are borrowed by the Library each year from external sources.

The British Non-Ferrous Metals Research Association

Continued from page 180

first probe is conducted through the coating and warms the interface between the coating and the basis metal to an extent depending on the nature of the coating and its thickness. The interface between the coating and the basis metal at the points under the hot probe and under the cold probes acts in a way analogous to the hot and cold junctions of a thermocouple and an e.m.f. is set up which is amplified and measured. For any particular type of coating this e.m.f. is directly proportional to the thickness of the coating and the instrument may be calibrated to read directly in terms of coating thickness. It can be applied to any single coating on any basis metal provided that the metal is a conductor, and it is suitable for determining the thickness of nickel in the ordinary decorative nickel chromium finish. A patent has been applied for and arrangements have been completed with two firms for the commercial manufacture of the instrument.

Shell Moulding Survey

An account of the Association's work is incomplete without some mention of the very comprehensive survey of shell moulding practice which has been made by a member of the liaison staff. This was done at the request of the Association of Bronze and Brass Founders, and was paid for in part by a contribution from the A.B.B.F.'s Conditional Aid funds.

Industrial surveys of this kind are no new thing to the Research Association, several having been made for members in the past. At the time of the acute shortage of metals and sulphur, for example, a survey was made of the methods being adopted to conserve available supplies, and more recently there has been one on the performance of steels and heat-resisting materials used for extrusion dies and tools, and for other hot-working operations, while another is at present being made of instrumentation in non-ferrous metal working plant. This survey of shell moulding is, however, the first which has been prepared for publication, the others having remained indefinitely on the confidential list.

In the case of shell moulding, the aim was to present to the foundry industry an unbiased picture of the present state of this process, the equipment available, and the potentialities, while at the same time enabling a member of the B.N.F. staff to obtain enough experience of the process to act as an adviser on its applications. The report which resulted from the survey has met with unqualified success, and hundreds of copies have been distributed to the Association's own members and, through the A.B.B.F., to non-member firms both here and abroad. So encouraging has the response been, that the A.B.B.F. has asked for a similar investigation to be made into the carbon dioxide process for hardening cores and moulds, and a report is now in course of preparation.

The British Welding Research Association

By H. E. Dixon, M.Sc., A.I.M., A.M. A.M.Inst.W
Chief Metallurgist

THE total income of the Association for the year ending March, 1955, has reached a record of £148,676 which compares with £113,369 for the previous year. A corresponding increase in membership is shown; in April, 1955, there were 309 ordinary members and 33 associate members, the appropriate figures for April, 1954, being 274 and 31 respectively. By July, 1955, the membership increased to 328 and 33 respectively. This growth in income and membership is extremely encouraging, and is indicative of the general increase in research activities and increasing industrial interest in the work of the Association.

A sum of £12,000 has been obtained from American Foreign Operation Administrations Funds to be spent over the period 1st March, 1955, to 31st December, 1956, to provide increased advisory services for the encouragement of welding productivity. Lecture courses are being organised in many centres in Great Britain and booklets and pamphlets are being written on numerous aspects of welding.

Some 31 confidential research reports have been issued to members during the year, covering progress on the main lines of research by the Association. At the same time thirty papers have been published in the technical press, and over thirty lectures given by members of the staff. Extensive use has been made by member firms of the Association's liaison services, which have maintained a close contact between research and welding problems in industry.

The Summer School on Welding is now firmly established as an annual event. At the fifth school held in June–July, over 230 students attended. There were nearly forty lecturers and an exhibition of testing methods was held in connection with demonstrations of non-destructive testing.

The growth of the metallurgical researches is now very much limited by the space available at Park Crescent. A new laboratory is in course of erection at Abington, and construction should be completed in May–June, 1956. This laboratory will provide about 13,500 sq. ft. of floor space and, in addition to general laboratory requirements, includes welding shop, machine shop and stores. (The photograph in Fig. 1 shows the erection of the structural steelwork).

It is hoped that all the metallurgical researches will be transferred to Abington by the autumn of 1956. Work on heat flow in welding has already been transferred, and arrangements have been made for much of the welding and testing of self-adjusting arc welds in steel to be undertaken at Abington, utilising existing facilities.

Metallurgical Researches

New Work—Ferrous

Two new ferrous researches have been commenced during the year: the self-adjusting arc welding of steel, and an investigation of the factors controlling the incidence of fissuring in mild steel and alloy steel weld metal. The former research is a matter of considerable topical interest. An important problem is the elimination of weld metal porosity, which largely results from a continuation of the steelmaking reaction:

$$C + FeO \rightleftharpoons Fe + CO$$

A theoretical treatment has been made of the deoxidation reactions which could be utilised to prevent the evolution of carbon monoxide and consequent porosity. The effect of welding conditions on weld penetration and weld contour and dilution of the filler metal by the parent plate have been investigated, using a commercially available filler wire. There is some evidence that, although it is possible to prevent porosity by deoxidation additions in the filler wire, if the carbon content is high, the weld metal may be sensitive to hot cracking. Arrangements have been made for the preparation of a series of experimental filler alloys for use with mild steel (killed and rimming quality) and alloy steels. The availability of these wires should enable a more detailed investigation to be made of the factors controlling porosity and weld cracking in a number of steels.

Fissuring is a form of micro-cracking (identified as cleavage fracture) in weld metal, which occurs during the cooling of the weld at temperatures from 150–120° C. Fig. 2 shows some typical fissures in a mild steel weld metal. Similar cracks have been produced in mild steel specimens cathodically charged with hydrogen (compare Figs. 3 and 4). The effect of hydrogen on ductile fracture under a tensile load has been investigated, and it has been shows that hydrogen increases the initial slope of the work-hardening curve of the stress-strain diagram, and this increase in hardness has been confirmed by slow-load hardness tests. Failure in tensile test specimens

Fig. 1.—New metallurgical laboratories in course of construction.

Fig. 2.—Fissures in mild steel weld metal made with rutile type electrode (electro-polished). ×10

containing hydrogen occurs by cleavage, and the results of microscopical investigations have suggested that cleavage fracture occurs after slight plastic yielding, which may result from a pressure of molecular hydrogen at interfaces in the ferritic matrix, or from the presence of an external load such as restraint.

The effect of hydrogen on work hardening is being examined further for a number of steels in various conditions of heat treatment. The presence of fissures may reduce the ductility of weld metal. They may be largely eliminated by the use of low hydrogen electrodes.

New Work—Titanium and Zirconium

A new research team has been established for contract researches on the weldability of titanium and zirconium alloys. Facilities have been provided for automatic tungsten arc welding in an enclosed chamber, using inert atmospheres.

High Strength Weldable Structural Steels

Good use is now being made of the equipment developed for the automatic determination of dilatation curves for preselected heating and cooling cycles. This has greatly facilitated the production of continuous cooling transformation diagrams, and it is hoped to produce an atlas of such diagrams in due course for structural and constructural steels.

A 2-ton cast of an experimental Mn-Ni-Cr-Mo steel has been made to the following composition :

C 0·11—0·15%
Mn 1·1 —1·4%
Ni 1·0 —1·2%
Cr 0·9 —1·1%
Mo 0·2 —0·235%

Preliminary tests have shown that the steel has good weldability, and a comprehensive series of tests on mechanical properties under various conditions of heat treatment is being made.

The weldability of a series of twelve experimental steels with varying molybdenum and vanadium contents has been examined. The behaviour of these steels was unusual in some respects ; in particular, it was found that no heat-affected zone cracking was obtained with very fast rates of cooling, i.e., a critical cooling range exists in which cracking occurs, but above and below which no cracking occurs. This same behaviour has been observed with a number of other steels, and further work is proposed to elucidate the relative effects of hydrogen, cooling rate, composition and restraint. The weldability and continuous cooling characteristics of a number of plain high carbon steels have been investigated. For low alloy steels, it was previously shown that, under given conditions, the end-of-transformation temperature (austenite to martensite or austenite to bainite) is related to the incidence of heat-affected zone cracking. No such relationship has been observed with the high carbon steels, and further carbon steels are now being examined.

Constitution of Weld Metal (Ferrous)

The mechanical properties of weld metal are being determined at temperatures up to and in excess of 1,400° C. Preliminary tests were made using notched specimens of weld metal in an argon atmosphere, and it was found that ductility drops sharply at temperatures in excess of 1,400° C. This may be due to the presence of liquid films at grain boundaries, and further tests are being made with un-notched specimens of different weld metal compositions. The properties of weld metal made with proprietary electrodes have been compared, and data on chemical analysis, dilatation and strain-ageing characteristics, and hydrogen content have been obtained.

A wide range of proprietary electrodes has been classified in terms of hot crack sensitivity using the Murex hot crack testing machine. In this test, a fillet weld is made under controlled conditions, whilst one test plate is rotated through 30° in relation to the other. The speed of rotation can be altered to suit the gauge of electrode and the severity of the test. The length of the crack indicates the cracking tendency of the electrode-plate combination. The behaviour of a number of special electrodes has also been examined, and the preliminary results show that the incidence of hot cracking is related to the Mn/S ratio—the higher the ratio the less the cracking.

An attempt has also been made to identify microscopically the inclusions present in the various weld metals, but this has not been successful. In an extramural research at Northampton Polytechnic, useful progress has been made in the extraction of inclusions by chemical methods, and their examination by X-ray diffraction and electron microscopy. Much work, however, remains to be done on these aspects.

Fig. 3.—Typical fissure in as-deposited weld metal. ×1000

Cracking in Welded Gas Mains

Some years ago it was shown that stress corrosion cracking of welded gas mains could be prevented by stress relieving. In an extra-mural research at King's College, Newcastle, an attempt has been made to identify the corrosive media in the gas mains, and cracking has been produced in the laboratory with ternary mixtures of hydrogen sulphide, ammonia and hydrocyanic acid. Further work is necessary to establish the composition limits of the solutions producing cracking. A statistical survey has also been made of the analysis of liquors sampled from gas mains at various plants over a long period, and the results of this survey are now being assessed. Tests are also being made on the suitability of low temperature localised stress relieving techniques, with particular reference to welded pipes.

Oxygen Cutting

Earlier work was concerned with fundamentals of the iron/oxygen combustion and the measurement of preheat flame efficiency. This latter work showed that preheating flame efficiency tended to decrease with increasing plate temperature, indicating appreciable heat loss by re-radiation or convection. Considerable cutting speed increases were possible with normal surface heating flames. It was possible to maintain a cut in small preheated specimens with cutting oxygen alone, but the same success was not obtained with larger specimens. Nevertheless, with similar gas flow rates, plate at 500° C. could be cut about twice as fast as plate at atmospheric temperature. A new apparatus is being designed to cut small annular specimens with oxygen only, to study combustion conditions without the complication of flame.

Pressure Welding

In previous work by Tylecote at King's College, Newcastle, it has been shown that the ratio of the hardness of the surface oxide film to the hardness of the underlying metal is related to the critical deformation necessary for pressure welding, critical deformation being defined as that deformation at which maximum weld strength is achieved, or that deformation beyond which increased deformation does not produce a corresponding increase in weld strength. It should, therefore, be possible to increase the weldability of metals of poor weldability,

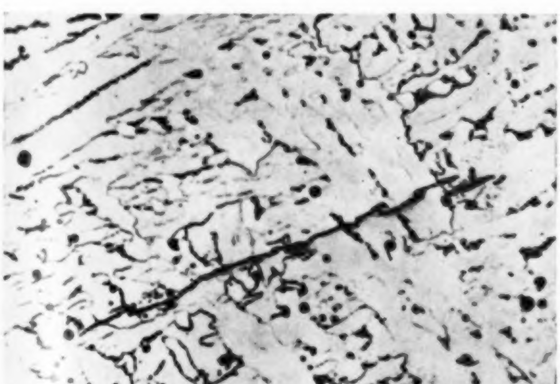


Fig. —Brittle crack in weld metal induced by cathodic charging with hydrogen.

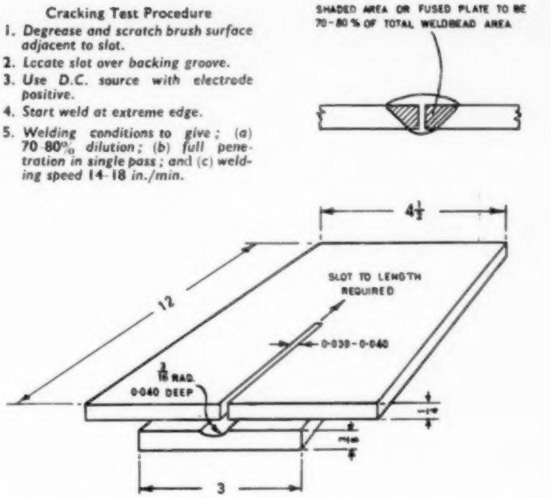


Fig. 5.—Slotted butt-weld cracking test specimen (metal arc electrodes).

such as zinc, cadmium and silver, by suitable additions of an element which would oxidise preferentially, and give a hard oxide without too large an increase in base metal hardness. The effect of aluminium additions to zinc and to silver, and of magnesium to cadmium, has been investigated, and although the work is not yet complete, some general improvement in weldability has been obtained.

The room temperature oxidation properties of several pure metals have been examined by Tylecote, and an attempt made to calculate oxide film thicknesses.

Metal Arc Welding of Medium Strength Al-Mg-Si Alloy H.10

Cracking experienced in the butt welding of thick sections of H.10 alloys, using Al-5% Si filler metal, was attributed to the dilution of the filler metal by the parent material producing a crack-sensitive composition. An accurate knowledge of the magnitude of the dilution effect has enabled weld metal composition to be predicted accurately and, by the use of suitable fillers, generally of higher silicon content, has provided a solution to the problem of weld cracking. A number of ternary alloys based on Al-10% Si have been made to develop improved alloys for welding H.10 alloy (metal arc and argon arc). The complete avoidance of weld metal porosity has proved to be an almost intractable problem. Even when all free moisture has been removed from the electrode coating by drying, combined moisture in the coating and hydrated corrosion products on the surface of the core wire produce significant porosity. The possibility of protecting the wire from the corrosion which occurs during storage of the electrodes will be examined.

A new cracking test has been devised to assist electrode manufacturers in the development of new electrodes. This is known as the slotted-butt weld cracking test. It simulates the square-edge close-butt condition. In this test a single rectangular plate is used of standard dimensions without external restraint and containing a slot cut from the centre of a narrow edge and parallel to the long side. (Fig. 5). The welding current is adjusted to give full penetration and the desired amount of dilu-

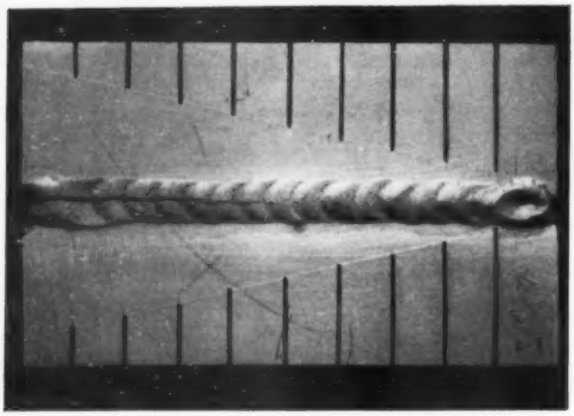


Fig. 6.—" Fishbone " cracking test piece in heat treatable aluminium alloy ($1\frac{3}{4} \times 3$ in. for 16 s.w.g. material).

tion. The degree of restraint decreases as the slot is lengthened and several tests are made to determine the slot length at which cracking fails to occur.

Argon Arc Welding of High Strength Heat Treatable Alloys

Present work has been confined to the welding of duralumin type alloys and an Al-Zn-Mg-Cu alloy, in thicknesses from 16 of s.w.g. to $\frac{1}{4}$ in., although some work has been done on material as thick as $\frac{1}{2}$ in.

Preliminary tests showed the need for filler alloys of increased strength and crack resistance, and a systematic investigation was made of the alloy systems Al-Zn-Mg and Al-Cu-Si. Some thirty special alloys were made, and besides tensile properties, ageing and cracking susceptibilities were determined on the welds made with these fillers. A simple cracking test was developed which is economical in material, easy to use, and suitable for assessment of cracking tendency of the parent plate, alone or with addition of filler metal. This test, known as the " fishbone " test has been successfully used for a variety of aluminium and magnesium alloys in thicknesses from 16 s.w.g. to $\frac{1}{8}$ in. Its application to thicknesses up to $\frac{1}{4}$ in., and to ferrous materials, is now being examined. A photograph of the test piece used is shown in Fig. 6.

By selection of filler alloy and welding technique, a useful improvement in the properties of welds in Al-Cu-Mg-Si and Al-Zn-Mg-Cu alloys has been obtained in the as-welded and as-welded and artificially aged conditions.

The conditions for grain refinement in welds are also being examined.

Electrical Characteristics of the Self-Adjusting Arc Welding Process

Very useful progress has been made by the Electrical Research Association in a co-operative research on the characteristics of the self-adjusting arc process. A marked improvement in self-adjustment occurs with power sources having a flat output characteristic and an open circuit voltage approaching that of the arc. With this type of source, the presetting of welding condition is simplified, since the welding current is predetermined by the wire feed speed. Drift in the electrode feed rate and arc parameters has been measured for commercial welding equipment. Drift in output was greatly reduced with a low voltage generator, and was negligible with a flat characteristic transformer rectifier. A servo system depending on arc voltage was developed which compensates for drift in normal generators (i.e., those with drooping characteristics) by adjusting the field regulator or by alteration in the rate of wire feed speed.

The initial work disclosed the need for a special welding head, for research purposes, giving accurate control of the welding variables. This equipment has been constructed (see Fig. 7), and is being used for a comprehensive study of the overall relation between arc voltage, arc length, welding current and electrode burn-off rate. A detailed examination of the metallurgical properties of the corresponding welds is also being made. The tests are being made initially with aluminium alloys, but it is hoped to include both ferrous and copper alloys at a later stage.

Self-Adjusting Arc Welding of Al-Mg Alloy NP5/6

Porosity is very largely a characteristic of self-adjusting arc welds in aluminium alloys, although it is usually very much less than that present in metal arc welds (coated electrodes). The present investigation is largely concerned with the effect of wire surface treatment, thermal cycle and welding conditions, and is closely integrated with the programme at the Electrical Research Association.

A standard method has been developed for assessing and classifying porosity from microscopical examination which shows many advantages over radiographic examination. It is hoped that this new method will be widely used, and will thus make possible a direct comparison and correlation between the results from different research workers. A correlation between porosity and mechanical properties is also being attempted. Although the complete elimination of porosity is difficult, porosity levels less than $0 \cdot 1\%$ are attainable with commercially-available wires, using the correct welding conditions. It is doubtful whether porosity levels of this

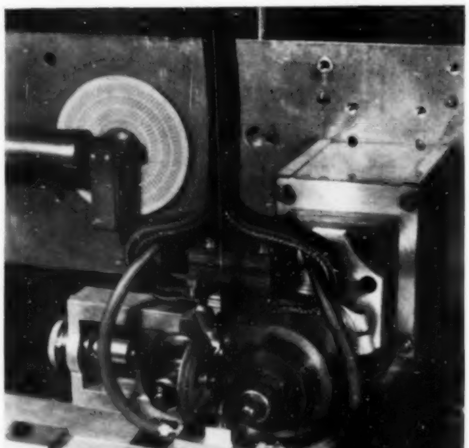


Fig. 7.—The E.R.A. welding head for investigations on the self-adjusting arc process.

order have any significant effect on the mechanical properties of the weld metal.

Heat Flow in Welding

A knowledge of the thermal cycle during welding is of importance, not only in alloy steel welding, but also in the welding of both work-hardening and heat-treatable aluminium alloys. The application of mathematical methods to the prediction of thermal cycles in welded aluminium alloy has been shown to be limited by the lack of information on the heat input to the plate for predetermined welding conditions. Accurate measurements of heat input have been made for a range of welding conditions, and an estimate has been made of heat loss in the argon shielded tungsten arc ; about 50%–60% of arc energy goes into the plate, about 25% is lost by radiation and conduction in the torch (cooling water losses) and rather more than 6% by gaseous conduction (argon losses).

The development of simplified mathematical methods for predicting thermal cycles is also being considered.

Resistance Welding Researches

Projection Welding

The existing code of practice on projection welding (T.30) covers mild steel in the thickness range 20 to 14 s.w.g. Tests are now being made to extend the range to both 12 s.w.g. and 10 s.w.g. sheet. The conditions for making single projections in 12 s.w.g. sheet have been determined, and provide a basis for evaluating the conditions for both double and triple projections.

Some work has also been done on the attachment of $\frac{5}{16}$ in. shank diameter headed studs to $\frac{1}{2}$ in. thick plate, and suitable welding conditions have been recommended. Preliminary tests have been made on the welding of bosses with annular projections.

Fig. 8.—General view of torsion testing machine.

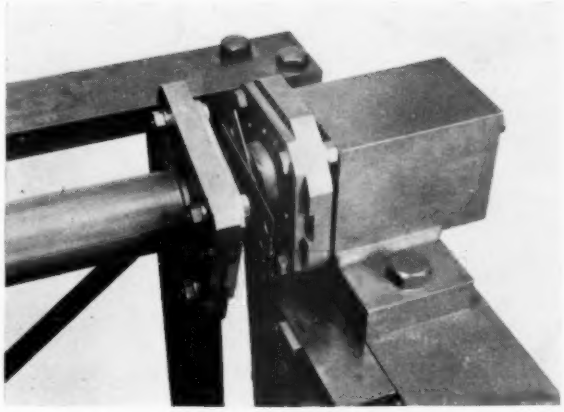


Fig. 9.—Torsion testing machine showing location of specimen on fixed head.

Spot Welding

A mathematical analysis of heat flow in spot welding has been made which provides a basis for the calculation of welding conditions for the spot welding of hardenable steels. A comparison of theoretical and measured temperature cycles for spot welds in $\frac{1}{16}$ in. and $\frac{1}{8}$ in. thick mild steel has shown satisfactory agreement, and will be extended to other thicknesses and materials. It has been shown that cooling time (which mainly determines the weld hardness) is primarily dependent on weld size and the speed with which the electrodes are separated after welding.

A multi-stage spot welding control system has been installed and calibrated. This will enable a variety of post-heating cycles to be used in the spot welding of hardenable steels and, in particular, a weld, quench, grain refine, quench and temper sequence.

The ductility of spot welds in hardenable steels has been assessed in a number of ways ; by hardness, the ratio of shear tension strength, and microscopical examination, and, more recently, by torsion testing. It has been suggested that the fracture appearance of the weld tested in torsion gives sufficient indication of weld ductility. A special torsion testing machine has been constructed which gives a graphical record of the torque strength and angle of failure. (Fig. 8). Basically, the machine consists of a stiff frame carrying a rotating head and a fixed head, the energy from the rotary head being transmitted to the fixed head by the specimen (Fig. 9). Energy is supplied by a geared motor through a system of reduction gears giving the rotating head a fixed speed of 3·9 r.p.m. The fixed head is prevented from rotating by a torque arm, the reaction from this being taken on a cantilever beam fitted with electric-resistance strain gauges. The output of the strain gauge network is arranged to produce a signal on a C.R.O. which may be photographed.

Engineering Researches

Load Carrying Capacity of Frame Structures

Research into the following aspects of the plastic theory has been undertaken during the year :

1. design and behaviour of stanchions in the plastic range ;
2. practical tests on full-scale frames loaded to

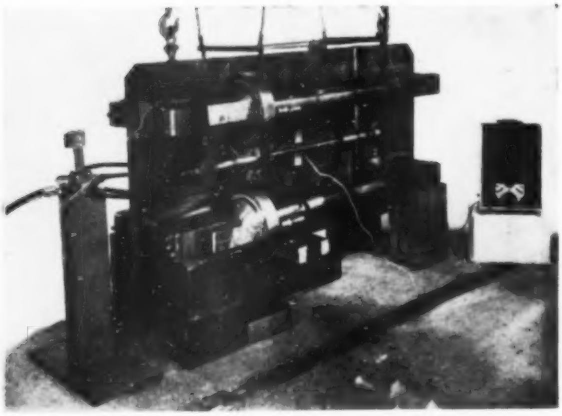


Fig. 10.—Testing rig for generating brittle fracture in 36 in. wide steel plate.

collapse, including the behaviour of natural foundations ; and

3. effect of machined notches, weld runs and joints upon the onset of fracture at low temperatures in light rolled steel sections loaded in bending.

A design method based on designing the stanchions to give maximum support to the beams in a multi-storey frame has been evolved, and its application to typical cases is being investigated. A full account of the theoretical work on the behaviour of plane stanchions has been completed. In the full scale frame test it has been demonstrated that quite modest mass foundations can develop the full plastic moment of a stanchion base. The behaviour of foundations is being investigated further.

Notches of considerable depth may precipitate fracture in mild steel joists at loads up to those sufficient to produce full plastic moments, and this will be brittle if the temperature is below the transition temperature. The effect of small notches and weld runs without undercutting may generally be disregarded.

It is interesting to note that over 150 buildings designed by the plastic method have now been erected, or are in course of erection, and that the structural steelwork for the new metallurgical laboratories has been designed by this method.

Welded Structures under Dynamic Loading

S/N curves extending to 2×10^6 cycles have been determined for plain plate (control) and butt welded plate of $1\frac{1}{4}$ in. and $\frac{1}{4}$ in. thick material, using pulsating tension. Small fatigue specimens have also been taken from the stressed and unstressed parts of the large fatigue specimens to compare fatigue properties and the effect of removing the surface layers : the work on small specimens is being undertaken at the Metallurgical Department, Cambridge University. The behaviour of good quality butt welds made with brittle and low-hydrogen electrodes has been compared with the behaviour of plain plate under impact-tension loading. The energy necessary to produce failure (which occurred away from the joint) was the same as for the plain plate. No major differences were observed for welds containing cracks and slag inclusions, although useful information was obtained on propagation of weld defects as a result of the test loading.

The behaviour of welded thin gauge (16 s.w.g.) constructions under various forms of fatigue loading has been further investigated. Five types of box-section beam have been tested, using alternating plain bending about major and minor axes, and alternating torsion. Alternating bending is also being used in a new series of specimens to determine the influence of the quality and spacing of spot welds and the comparison of continuous with intermittent fillet welds.

Testing of Welded Pipes and Pressure Vessels

The major aims of the present work are to determine the most economical method of reinforcing pressure vessel nozzles, and whether full penetration welds for the attachment of nozzles are significantly stronger under fatigue conditions than partial penetration welds.

The pressure vessel which was originally tested with three unreinforced nozzles was modified and six different reinforced nozzles attached. The external and internal stress distribution has been measured under static internal pressure, and good progress made in an analysis of the results. The fatigue tests on the effect of partial and full penetration welds are under way using 12 vessels, each 3 ft. long and 1 in. thick, with a 20 in. bore, containing a single nozzle, $6\frac{5}{8}$ in. bore and $\frac{3}{8}$ in. thick. Much of this work has now been completed, but a few vessels have still to be tested.

Work on the reinforcement of pipe branch connections has involved the measurement of stress distributions for different types of branch subject to various loading conditions. The forms of reinforcement used were a light collar, a "triform" reinforcement and a heavy collar. A special reinforcement employing a light collar and a girth horseshoe is now being tested.

Smooth seamless pipe-bends have been tested under a combination of alternating bending and static internal pressure. These tests supplement those made last year using alternating bending and pulsating pressure. Tests have also been carried out on pipe bends made from lengths of straight pipe (three-weld gussetted bend). Four types of loading have been used, namely, loads tending to increase the radius of curvature and loads to decrease it (both these being in the plane of the bend), torsion moments on one arm of the bend (out of the plane of bending), and internal pressure.

The effect of weld porosity, slag inclusions and lack of fusion on the fatigue strength of butt joints in 6 in. diameter mild steel pipes has been investigated. No significant reduction in fatigue strength was observed for either porosity or slag inclusions, but defects on the inside of the pipe, such as undercutting or lack of fusion, were very harmful.

Brittle Fracture in Steel

There has been a steady increase of activity in brittle fracture work during the year. The velocity of crack propagation has been calculated and found to agree with experimental observations for cracks in steel and other materials. A 600-ton test rig for generating brittle cracks in 36 in. wide plate up to 1 in. thick has been designed and constructed by a member firm (Fig. 10). A programme on $\frac{5}{8}$ in. thick plates has been completed. Tough steels butt welded to a brittle crack initiation plate, have been tested for ability to arrest cracks at 4° C. and 10 tons/sq. in. working stress : similar tests have been made on riveted crack arresters. Results show that even in a very tough steel well above its

(*continued on page 200*)

The British Iron and Steel Research Association

SERVING a large and complex industry, the British Iron and Steel Research Association is made up of five divisions : Iron Making, Steelmaking, Mechanical Working, Plant Engineering, and Metallurgy (General), and two Departments of Physics and Chemistry. To illustrate the Association's work, some typical examples chosen from recent research are described in this article, together with an outline of some special services provided for industry.

Reducing Charging Delays to Open-Hearth Furnaces

Studies of scrap supplies to open-hearth furnaces have shown that charging delays can be greatly reduced, and production increased, by careful planning and co-ordination of supply services, even without acquiring expensive capital equipment. These studies have shown that it is most important, not only to achieve a high average pan weight, but also to ensure that the weight of individual pans does not fall far below this average ; for the delays caused by charging bad scrap one day can never be fully recovered by charging heavy scrap the next. Average pan weights can be improved by carefully marshalling incoming scrap, by suitably preparing it, and by loading both light and heavy scrap into any one set of pans.

Although little can be done to prevent " bunching " of furnaces, its ill effects can be reduced by building up reserves of well-loaded pans during slack periods. To do this, loading must be given priority during any slack periods at the furnaces. If empty bogies are returned to the scrap shed without delay, charging cranes need not remain idle while bogies are standing empty on the melting shop stage.

To co-ordinate all the activities involved in taking scrap from loading bays to the furnaces is hardly possible while the responsibility is divided among many people. It is therefore recommended that every melting shop should have a raw materials shift foreman, responsible to the shift manager for the whole of the supply side. Effective supervision will enable the best use to be made of existing facilities, and will often achieve results comparable with those to be obtained by installing expensive capital equipment such as scrap presses or new loading bays.

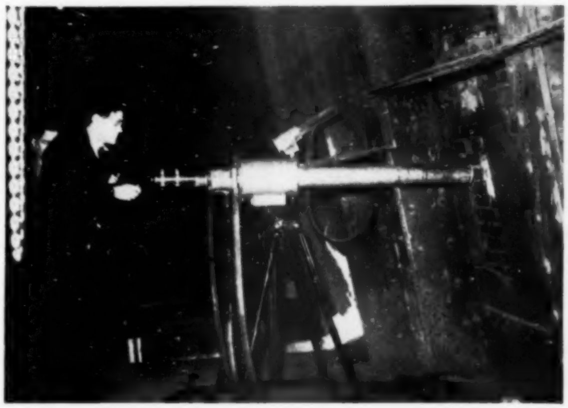


Fig. 1.—Furnace-scanning periscope being inserted through the back wall of an open-hearth furnace.

A Furnace-Scanning Periscope

A water-cooled periscope which provides a viewpoint within the walls of an open-hearth furnace while it is in operation has been built (Fig. 1), and is providing valuable information which could not have been obtained by any other means. Although this is not the first periscope to be built for viewing the interiors of furnaces, it is the most ambitious yet made. The present version is a general-purpose instrument. It has a water-cooled barrel, mounted on a stand, which carries at one end an eyepiece and at the other an optical head, containing a mirror and lens system, which provides three possible viewing directions, covering : (*i*) 0–40° from the axis of the periscope ; (*ii*) 40–80° from the axis ; and (*iii*) 80–120° from the axis. The barrel can itself be rotated on its axis. By this means a 240° panorama is

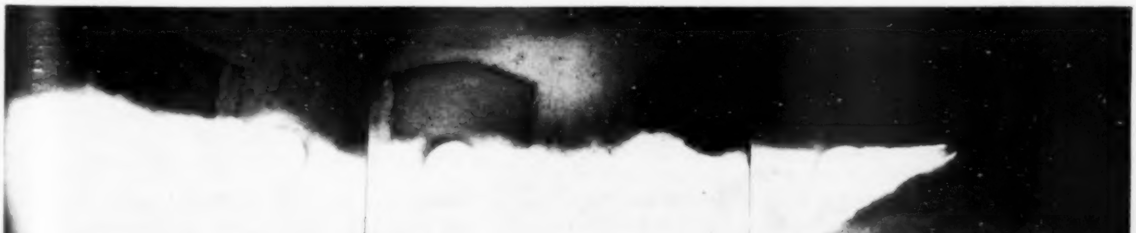


Fig. 2.—120° panorama of the interior of an open-hearth furnace, photographed through the B.I.S.R.A. periscope inserted through the back wall.

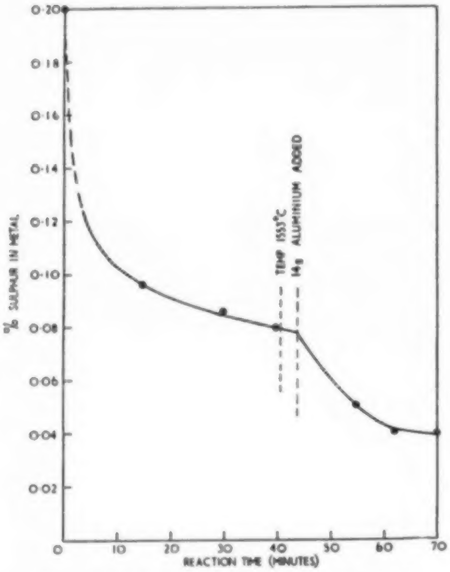


Fig. 3.—Effect of adding aluminium to molten iron and slag.

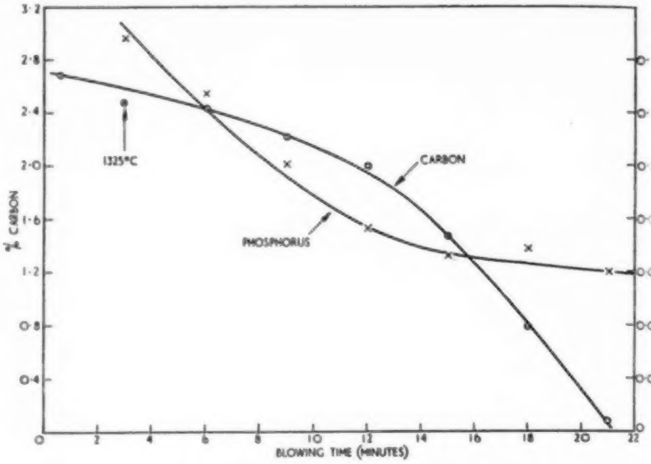


Fig. 4.—Removal of phosphorus from molten iron and slag by oxygen blowing.

obtained, and the whole of the interior of the furnace can be scanned from one position. The periscope can be used to study the melting of scrap, the shape and luminosity of flames, and the wear of refractories in the furnace. Its optical performance makes it suitable for almost any application requiring the examination of the interior of a furnace. The periscope has been used to photograph the interiors of open-hearth furnaces (see Fig. 2), and a film has been made in the works of a member firm which shows sequences photographed at intervals during two complete melts. Views of the interior of a furnace seen through the periscope have also been transmitted by closed-circuit television in a demonstration of industrial television at a works.

Physical Chemistry of Steelmaking

The chief aim of B.I.S.R.A.'s research on the physical chemistry of the processes of steel manufacture is to help steelmakers to predict accurately the composition of metal and slag at any moment, and to know exactly what changes to make in order to reach a desired end-product. Three current investigations by the Chemistry Department of B.I.S.R.A. concern the desulphurisation of steel, the desulphurisation of hot metal, and oxygen blowing.

Desulphurisation of Steel

The chemical evidence now available on the process of removing sulphur from molten steel shows that the distribution of sulphur between the slag and the metal depends on several factors: the temperature; the basicity of the slag; the degree of oxidation; and, to some extent, the composition of the metal. The combined effect of these factors is such that the capacity of the slag to hold sulphur increases with increasing basicity and decreasing oxidation. It has been possible to calculate from analyses of open-hearth slags the amount of sulphur present in the metal when equilibrium is reached; these calculations show that in most cases the distribution of sulphur between the slag and the metal has reached equilibrium by the time the furnace is tapped. Further work is now being done to discover why equilibrium is not always reached; at the same time, endeavours are being made to apply the results of the experiments to the practical problem of controlling the removal of sulphur.

Desulphurisation of Hot Metal

The influence of aluminium, manganese, and silicon on the rate at which sulphur is removed by slag from carbon-saturated iron has been studied. It has been shown that the addition of these deoxidants, which are known to react rapidly with dissolved oxygen, causes a marked increase in the rate at which sulphur is removed. Fig. 3 illustrates the effect of adding aluminium to molten iron and slag. This indicates that the critical step in the process of desulphurisation is the removal of oxygen, and that the reaction between carbon and oxygen in molten iron is sluggish. Laboratory experiments on a medium scale have shown that the amount of sulphur in hot metal can be rapidly brought down to low values by adding aluminium to a ladle of hot metal and slag.

Oxygen Blowing

Although the manufacture of steel by top blowing with oxygen is now an established practice on the Continent and in America, more information is required before the method can be used widely in this country. To provide the essential knowledge about the factors (such as the composition of the slag, temperature, etc.) which determine the way in which the refining reactions take place, a series of experiments is being carried out. In one of these, 2 lb. of fused slag (45% lime, 10% magnesia, and 45% silica) was placed on top of 20 lb. of molten iron containing 2·8% carbon and 1·8% phosphorus; a jet of oxygen was then turned on the mixture. During the experiment, the temperature of the melt rose from 1,300°C. to 1,500° C. Fig. 4 shows the changes in carbon and phosphorus contents of the metal during blowing. It can be seen that, even with a fairly acid slag, it is possible to remove phosphorus quite quickly, even when the carbon content is high. Work is now in progress to apply this method to the removal of phosphorus from pig-iron containing about 2% of phosphorus.

Fuel Economy in Soaking Pits

Heat equivalent to more than a millions tons of coal is used annually by the British steel industry in its

soaking pits, despite the fact that under good conditions an ingot contains about 5 therms per ton more heat when cast than when it arrives at the rolling mill. Surveys of works practice made by the Association have revealed variations in fuel consumption in British works ranging from 9·25 to 27 therms per ton (yearly average).

One of the main causes of heat loss is the practice of fixing an arbitrary " safe stripping time," which results in some ingots being left unstripped for much longer than necessary. By measuring the heat losses from cooling ingots the relations between ingot size and minimum safe stripping times have been established.

It has also been found that the temperature of the moulds has an important bearing on fuel consumption. The use of moulds at a consistent temperature (about 100° C.) materially shortens the waiting period, and also prolongs the life of the moulds themselves. Modern equipment for stripping and handling the ingots is also important in saving time and thus reducing heat losses.

One result of rising production is that in many works plant is operating far beyond its designed capacity. This inevitably causes congestion of the transport system between the melting shop and the rolling mills, and results in wide variations in the heat content of successive batches of ingots, so that some batches have to be heated for longer than the average time.

Steelmaking is essentially a " batch " process, but rolling is a continuous one. If two or more furnaces are tapped together (" bunching ") the rolling mills cannot keep pace with the supply of ingots. To accommodate the surplus, extra soaking pits beyond the theoretical minimum must be provided, and extra fuel must be used to operate them. It has been shown, however, that the effect of furnace bunching can be considerably reduced by stripping the first cast earlier and putting the ingots in " dead " soaking pits or " live " pits burning the minimum of fuel.

The appointment of a " programme controller " can greatly reduce the causes of heat loss. His function is to co-ordinate the operations of the melting shop, the rolling mills, and the internal traffic system so that the whole system works smoothly and with the minimum of " surges." With such planning the soaking pits can be employed economically and handling delays can be kept down to the unavoidable minimum. Plotting operations on a " planning board " has also been very successful, and this simple device could profitably be introduced into many works.

A great deal of fuel can be wasted in a soaking pit unless waste heat recovery, insulation, instrumentation and control, etc., are adequate. The efficient use of fuel depends largely on accurate control of the fuel and air supplies and on the pits being gas-tight. Adequate instruments are essential and automatic control is very desirable. This equipment will not only save fuel but will also improve the yield and quality of steel. A booklet published by B.I.S.R.A., ***Instrumentation and Control of Mill Furnaces***, sets out the principles involved, together with illustrative examples.

Research on Forging

Since the opening of the Sheffield Laboratories in 1953, it has been possible to extend and intensify B.I.S.R.A.'s research on forging. Among the most important of recent investigations are those into the rapid heating of ingots and the choice of tools and procedure.

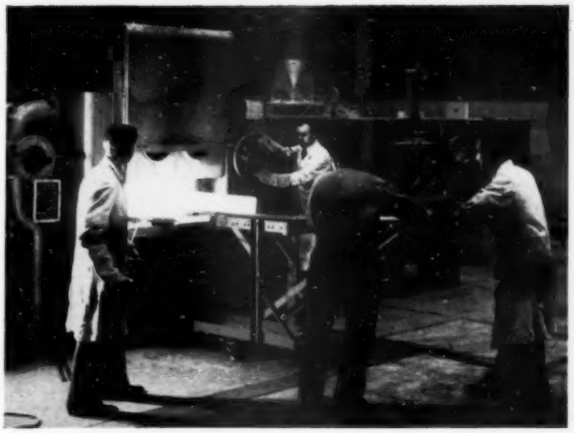


Fig. 5.—Removing an ingot of high-speed steel from one of the gas-fired furnaces at the Sheffield laboratories during an experiment on rapid heating for forging.

Rapid Heating of Ingots

The cost of heating the ingot is an appreciable part of the total cost of a forging operation. Besides saving fuel, rapid heating allows production from existing furnaces to be increased, eliminates troublesome decarburisation of certain alloy steels, and reduces scale losses. Experiments in the Association's Sheffield laboratories and in the works of member firms have shown that conventional heating times can be reduced by up to 90% in many instances.

At a demonstration at the Sheffield laboratories in March, 1955, small ingots of high-speed steel were successfully press-forged without soaking after being heated in two stages for a total time of less than an hour. The cold ingots were charged into a pre-heating furnace at 1,000° C., and as soon as they reached 400–500° C. were transferred to a furnace maintained at 1,250° C. This two-stage method minimises the costly risk of clinking, and the rapidly-heated ingots can be forged as readily as slowly-heated and soaked ones. For many steels, soaking at the forging temperature is evidently unnecessary, and great benefits and economies are to be obtained by rapid heating. Fig. 5 shows an ingot of high-speed steel being removed from the furnace.

Choice of Tools and Procedure

One result of reducing an ingot's section by hot forging is to alter its mechanical properties. An improvement in the longitudinal direction may, however, be to the detriment of the properties in the transverse direction. An externally measured forging reduction of, say, two or three to one is often quoted as being necessary to produce acceptable properties.

Investigations by B.I.S.R.A. indicate, however, that reductions measured externally are not in themselves a sufficient guide, because ingots forged to the same overall reduction may exhibit either uniform or variable properties in the interior (depending on the tool width and reduction per pass). It has been shown that the tool width and reduction per pass control the distribution of internal deformation, which in turn affects the properties. This is illustrated in Fig. 6. Data are now available which enable tools and forging sequences to be

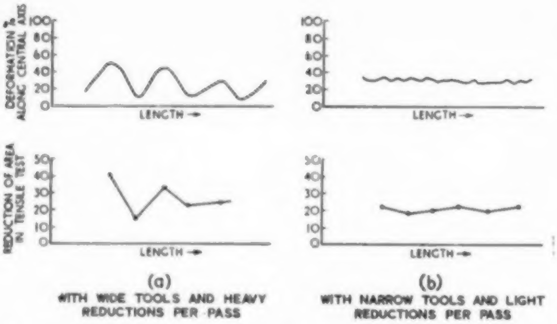


Fig. 6.—Deformation along central axes and resulting properties in two ingots forged to the same total reduction.

chosen for producing reasonably uniform internal deformation. Fig. 7 and the upper curves in Fig. 6 illustrate this point.

Die Blocks

Small die blocks are made from hot-rolled billet material, which exhibits far better mechanical properties in the longitudinal direction than in the transverse direction. Uniform properties in all directions are desirable in die blocks, and to this end upset forging is usually advocated. Repeated upsetting and drawing out is said to eliminate directionality more effectively than single upsetting. Fig. 8 shows how the properties of a particular billet material are affected by different upsetting operations. From laboratory investigations the optimum forging procedure to give the best distribution of properties can be specified.

Plasticine Experiments

Experimental results are not quickly obtained from bulky steel forgings; for example, during the investigation of die block properties mentioned above it was necessary to forge, heat treat, and subsequently cut up sixteen blocks, from which 160 tensile and impact specimens were machined and tested. A quicker and cheaper method of obtaining information about internal properties and deformation is to carry out experiments on Plasticine models. Model ingots or billets of the type shown in Fig. 9 are cheap and easy to make. After forging, sections can easily be cut through them to reveal the internal deformation, and the amount of deformation can be measured. (The upper curves in Fig. 6 were obtained in this way). By comparing the deformations in Plasticine and hot steel, after geometrically similar operations, it has been demonstrated that they have similar flow characteristics. Fig. 10 shows that the agreement is close enough to warrant the use of Plasticine models for investigating internal deformation, and, by inference, mechanical properties. From such studies, full-scale forging experiments under selected critical conditions can be devised and carried out on the laboratory plant.

Teleprinter Technique for Recording Numerical Data

Many routine records are made in steelworks and elsewhere on circular and roll charts, but because the labour of analysing them is prohibitive, full use is seldom made of all the information they contain. A method of automatically handling large quantities of numerical data has been developed which should find many applications in the steel industry and elsewhere.

Teleprinter perforators have been specially adapted by B.I.S.R.A. for recording the information. The technique has much in common with the punched-card systems widely used in accountancy and statistics, but teleprinter equipment has the advantages that it provides a continuous record and is much more compact. The adapted teleprinter perforators are now available from the manufacturers as standard items of equipment.

In normal operation the various characters (letters, figures, etc.) of which a message is composed are each represented by one or more holes punched in any of five positions or " tracks " across the width of the tape. Successive characters are punched one after the other along the tape. The equipment is designed to work at a speed of seven characters per second, but for recording purposes it can be operated at about fifteen characters a second.

The adapted perforator is electrically operated by impulses from the equipment under test. The holes which it punches in the tape represent, not letters and words, but numerical data or sequences of operations. The information recorded on the perforated tape can be analysed either by a simple relay analyser or, if the calculations are more complex, by an electronic computer. Some existing punched-card installations are also suitable for the purpose. The applications of the method fall into two distinct categories, " operational recording " and " instrument recording," requiring different techniques. In studying operational problems, chosen operations are simultaneously recorded with respect to time or distance, or some other independent variable.

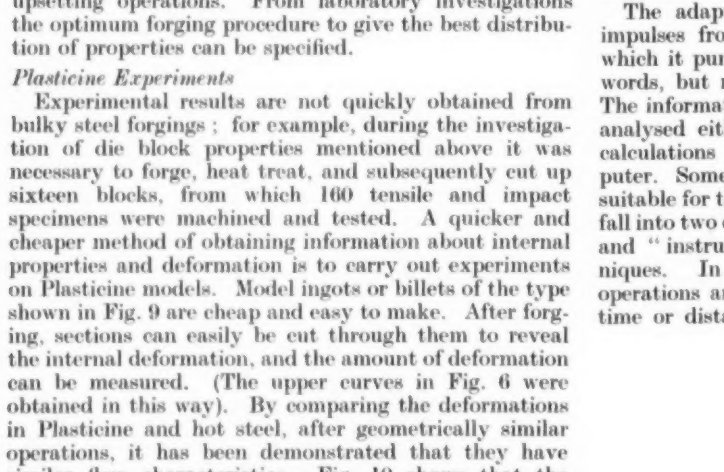


Fig. 7.—Effect of tool width on the distribution of deformation across a forged slab.

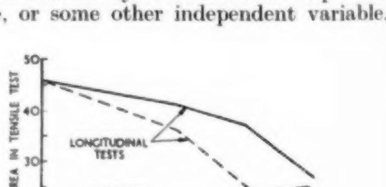


Fig. 8.—Effect of upsetting on the properties of billet material (solid lines—blocks upset once; dotted lines—blocks upset three times).

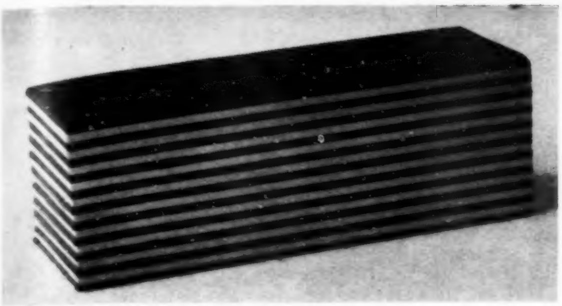


Fig. 9.—Model ingot made up of layers of Plasticine.

Instrument recording is analogous to continuous chart recording, numerical values of the chosen variables being recorded against an independent variable. In both cases, the adapted perforator receives from the equipment under test electrical impulses representing numerical data or sequences of operations, and punches holes in the tape according to a code.

The teleprinter technique has already been used successfully for analysing the operation of rolling mills and electric overhead travelling cranes. Methods for recording the operation of open-hearth furnaces have also been devised. There are many other operations to which the technique could profitably be applied, and it may soon be possible for teleprinter tape to replace continuous charts for many routine records.

Research on Cranes in Steelworks

Crane Structures

Cranes used in steelworks have been tested by the Plant Engineering Division of B.I.S.R.A. to find out how far the weight of crane structures can safely be reduced, and how structural defects can be prevented under continuous and heavy duty. The cranes already studied range from a small 4-ton ingot stripper to a 250-ton forging crane, and represent all the principal types used in the steel industry.

Tests have been made during normal use to determine loadings in the many varied operations performed in a steelworks, and their effect on crane structures. Abnormal loadings have been specially studied, and overloads of up to 100% have been recorded during the normal operation of forging cranes.

B.I.S.R.A. has devised a simple method of calculating the stresses in the four chord members of a crane bridge girder for any combination of vertical and lateral loadings. The validity of this method, which is based on the usual assumption that the girder can be treated as a pin-jointed structure, has been established by stress measurements on six cranes.

Although the investigations have shown that the structures of most types of cranes are broadly satisfactory, the low stresses recorded in certain of the tests indicate that some designers have not taken full advantage of the maximum permissible stresses, but have made over-generous allowance for the severe conditions in steelworks. Information now available on impact and fatigue conditions should make it possible to design lighter and more efficient cranes.

Gantry girders deflect and twist under load, causing "crabbing" of the crane and excessive wheel wear. A method of calculating deflections and stresses in complex

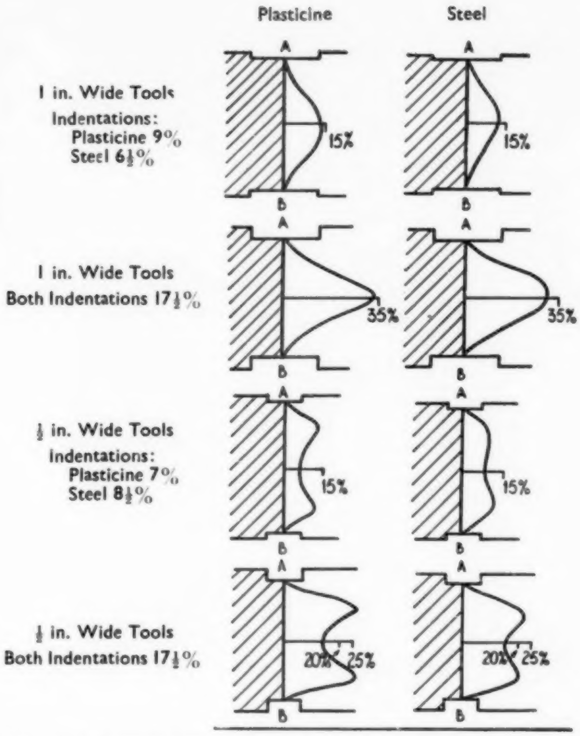


Fig. 10.—Comparison between strain distribution curves for similarly forged Plasticine and steel models.

girders has been developed and substantiated by tests on a full-scale gantry girder of 50 ft. span before and after its erection. It has also been possible to separate the vertical, lateral, and longitudinal dynamic effects of the crane on the gantry girder. A quarter-scale model of this girder is now being tested in the laboratory (Fig. 11); by modifying this model, the effects of changes in section will be studied.

Motor Drives

Without precise information on crane duties, and on the behaviour of electric motors under intermittent load-

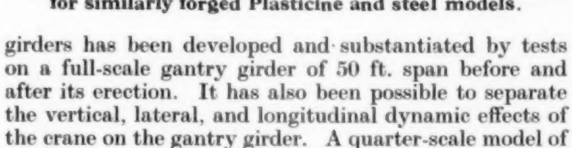


Fig. 11.—Model crane gantry girder in test rig for stress and deflection measurements.

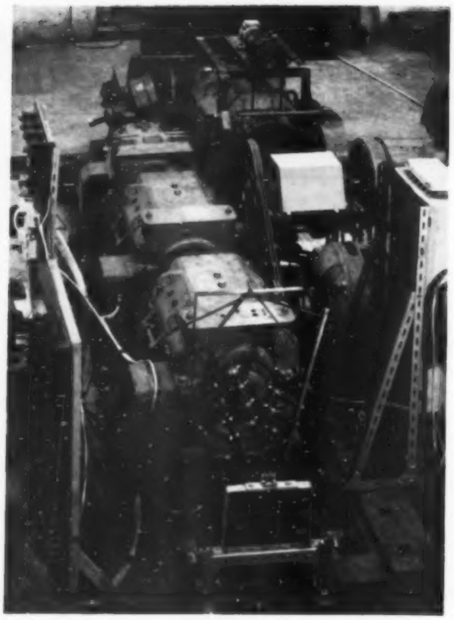


Fig. 12.—Electrical test bed, used for back-to-back tests of mill motors.

ing, the choice of motors and gear ratios for cranes is a difficult matter for designers.

To simplify this problem non-dimensional characteristic curves have been drawn for a range of mill-type motors, and a method has been laid down for using these curves in conjunction with chosen standards of crane performance (classified in terms of the time taken to travel the first 8 ft. and the speed attained after 10 seconds). Data on heating during intermittent loading are meanwhile being obtained in laboratory tests, in order to make it possible to estimate the insulation temperatures of motors under intermittent loading.

Crane Specification

A specification for heavy-duty electric overhead travelling cranes for use in iron and steel works was first issued by B.I.S.R.A. in May, 1950. A completely revised edition has recently been published in which an attempt has been made to reduce the weight and cost of cranes. The stress and deflection measurements mentioned above have been used in framing the revised stress and design clauses, and variable fatigue factors have now been introduced.

Crane Controls

However good an electrical or mechanical control, the best performance is only obtained if the crane driver can operate it efficiently. The cabs of many older cranes are far from ideal, mainly because the master controllers used in them are large and of unsuitable design. With the help of manufacturers of switchgear, B.I.S.R.A. has developed master controllers of four-start design, several of which can be grouped conveniently around the driver. Their control levers are vertical when in the central position and move only through relatively small angles, so that the operator's hand follows an almost straight and horizontal line. This makes it possible for the handle to move in the direction of the operation it governs, giving " realism " of control and consequently improved accuracy and greater speed. By combining two controllers, a single " joy-stick " control can be made to operate two motions, such as the long- and cross-travel movements of an electric overhead travelling crane.

The number and spacing of steps on a controller, the length of the handle, and the force required to operate it are among the factors that are being varied on a special controller in the laboratory to determine the best design. Studies of the frequency with which different notches on the travel motions of steelworks cranes are used have indicated that three steps are often adequate.

Quite sensitive control is possible with the foot, and experiments are therefore being carried out on foot controllers with the aim of using them in crane cabs. The best position (relative to the driver's ankle) for the pivot of a foot controller has already been determined.

Protection of Structural Steelwork

Four investigations into the protection of structural steel by paints, which were begun by B.I.S.R.A. and the British paint industry between 1945 and 1948, are now beginning to yield interesting results, and a report, *Painting of Structural Steelwork,* has recently been issued by the Joint Technical Panel J/P1. Two of these investigations are concerned with priming paints ; the third with painting over metallic coatings on steel and with various methods of surface preparation ; and the fourth with tar and bitumen paints.

In each of the four investigations, the protective properties of the paints have been assessed in parallel series of exposure tests at two sites : one, near the railway line at Derby, in a typical industrial atmosphere ; the other on a hill near the sea at Brixham, where there are long periods of sunshine and little atmospheric pollution. The contrast between these two environments is illustrated by the fact that bare steel corrodes about three times as quickly at Derby as at Brixham.

For weathered steel, priming paints in linseed-oil medium have proved better than those in all other media tested, and one pigmented with a mixture of red lead, white lead, and asbestine is recommended. Good results have also been obtained from priming paints pigmented with aluminium powder, basic lead sulphate or zinc oxide, with or without asbestine, in an alkyd medium, and by pigmented paints derived from blends of the natural bitumen gilsonite and various drying oils.

Technical Services

Besides its research activities, B.I.S.R.A. provides various technical services to answer the day-to-day questions of those who make steel and those who use it. The enquiries dealt with vary from questions which can be answered in the course of a short telephone call to problems requiring special investigations in B.I.S.R.A.'s laboratories, or in the works of the firms concerned. However large or small the question, and whatever its subject, the Association's object is the same—to offer practical help and achieve the closest possible contact with industry, and to encourage the use of the results of research.

Two services that are used very widely, both by members of the Association and others, are the Steel Users Section and the Corrosion Advice Bureau. Problems of organisation, handling and the flow of materials

encountered in the works of member firms are studied by the Operational Research Section's Advisory Team. A more specialised service is the supply of samples of analysed and tested steels to research workers.

The Steel Users Section

From its headquarters at Sheffield, in the centre of the special steel industry, this section answers technical enquiries and undertakes short-term investigations concerned with the uses of steel, as well as maintaining close contact with the smaller of B.I.S.R.A.'s member firms. To answer enquiries the section can call on the resources of all the various divisions and departments of the Association as well as those of other services such as the Corrosion Advice Bureau. Member firms having specialised knowledge and experience often freely give advice and help in answering their enquiries. Problems already investigated have concerned products as dissimilar as hypodermic needles and Centurion tanks.

The section maintains contact with member firms, especially the smaller ones, by periodical visits. Such visits, besides establishing close relations with member firms, provide valuable opportunities for discussing their technical problems on the spot.

The Corrosion Advice Bureau

This Bureau was formed in September, 1954, to deal with the rapidly increasing volume of enquiries for advice on corrosion problems. Research on corrosion initiated by the Iron and Steel Institute over a quarter of a century ago has been continued by B.I.S.R.A. since its formation in 1945.

Publicising the results of corrosion research is of prime importance in the fight against rust, and the results of new advances are reported in the technical press as well as in the journals of learned societies. Booklets are also published from time to time. Further publicity is obtained at exhibitions, conferences, and symposia, especially those of the Corrosion Group of the Society of Chemical Industry. Nevertheless, to rely on these methods alone would be to preach mainly to the converted. It is no less important to reach engineers and others engaged in manufacturing, building, and shipbuilding—in fact all the many industries which use iron and steel and face the attendant problems of corrosion.

It was primarily to serve this larger group that the Corrosion Advice Bureau was formed. It advises on any problem related to the corrosion of ferrous metals, and has the services of acknowledged experts at its disposal. The service is free to members, unless special investigations are entailed, and is also available in appropriate circumstances to non-members on a fee-paying basis.

The problems received are diverse in the extreme. A provincial water authority reported corrosion damage to buried pipes in an aqueduct system ; a gas company in an industrial centre had unsatisfactory results after painting the outer sheets of its gas-holders ; and a steel company experienced severe corrosion of a steel chimney. A problem of a different kind came from a fish-meal factory where production was suffering because of corrosion of the helical feeds conveying the product through the plant. In these and in many other cases the Bureau has recommended measures to prevent or reduce the corrosion.

Operational Research Advisory Service

An advisory service has been operated by the Operational Research Section of B.I.S.R.A. since 1953. The service was instituted to meet requests from the industry for help in improving productivity, and was made possible by a grant from the Conditional Aid funds of the Mutual Security Agency. Most of the work done has been concerned with problems of layout and handling, production planning and control, quality control, economic assessment, and organisation and methods.

When an investigation is undertaken, one or more members of the Advisory Team visit the works, staying up to a fortnight or even longer to study the problem and to collect the necessary information. Wherever it is of advantage, the Team can call upon the specialised knowledge of research workers in the Association's laboratories. The primary purpose of each investigation is to make recommendations on the problem under review, but the investigators may return to the works to help in putting their suggestions into practice. The diversity of the Team's work is best illustrated by quoting a few examples. One firm was puzzled at the inability of one of its finishing departments to restore output, which had understandably fallen during a period of trade recession. Investigation revealed that the fall in output was caused, in part, by preference being given to outside orders at the expense of the firm's own finishing department. As a short-term remedy, it was suggested that a buffer stock should be built up to put the finishing department under pressure of work. This expedient was adopted and had the desired effect. It was also suggested that planned production would provide the best long-term solution to this problem.

Another firm had successfully entered the American market with a product, but found that it was losing some of the new business after complaints about quality. The Team's studies showed that there had, in fact, been no falling off in the firm's own standards ; the crux of the matter lay in the different interpretations of quality specifications by the maker and the customer. Once this had been established the cure was merely a matter of devising adequate production controls.

A third firm was uncertain whether an old-fashioned manufacturing unit was still paying its way, or whether it was being " carried " by the more modern sections of the organisation. This resolved itself into a study of comparative costs, the necessary technical knowledge being provided by specialists within the Association.

In all cases where investigations have been made, definite recommendations have been put forward. The detailed reports and suggestions made remain confidential to the firms concerned.

Steels for Research Purposes

A service of a quite different kind has been initiated for the benefit of other research workers. The Metallurgy Division of B.I.S.R.A. has established a " bank " of analysed and tested iron and steels at its laboratories in Sheffield. The stock comprises samples from over 60 casts, and includes a number of steels referred to in the Iron and Steel Institute's publications. In addition, a limited quantity of special high-purity iron is available. A test certificate is issued with each sample, giving all available data on its composition, cast history, heat treatment, and mechanical properties. The advantage of being able to compare results directly with other workers who have used the same materials with accurately-known and fully documented characteristics needs no emphasis.

NEWS AND ANNOUNCEMENTS

Cable Sheath Corrosion Protection

A SYMPOSIUM on the Protection of Cable Sheathing against Corrosion is being arranged by the Corrosion Group of the Society of Chemical Industry to take place on Friday, November 18th, 1955 at the Institution of Electrical Engineers, Savoy Place, London, W.C.2. The following five papers will be presented and discussed: "The 'Phenol Corrosion' of Lead" by R. L. Davies and E. L. Coles (British Insulated Callender's Cables, Ltd.); "Cathodic Protection of Telecommunications Cables" by J. Gerrard and J. R. Walters (G.P.O.); "The Protection of Buried Power Cables" by J. H. Gosden (Central Electricity Authority); "The Behaviour of Aluminium-Sheathed Cables" by P. A. Raine (Johnson & Phillips, Ltd.); and "The Mechanism of Corrosion of Metal Pipes in Soils, and Practical Methods of Prevention" by W. W. Robson and A. R. Taylor (Associated Lead Manufacturers, Ltd.). Further details and forms of registration may be obtained from the Society of Chemical Industry, 56 Victoria Street, London, S.W.1.

Productivity by Welding

THE British Welding Research Association has arranged a number of meetings on increasing productivity by the use of welding, to be held at various centres throughout the country. The third meeting is in Birmingham on Wednesday and Thursday, 9th and 10th November, 1955, and will be held in the College of Technology, Suffolk Street. The fourth meeting of the series will be held in the Lesser Free Trade Hall, Peter Street, Manchester, on Tuesday and Wednesday, 13th and 14th December. Recent developments in welding various materials will be discussed, along with problems such as failure by fatigue and brittle fracture. Further particulars of these meetings can be obtained from The Organiser, British Welding Research Association, 29, Park Crescent, London, W.1.

Aluminium in Shipbuilding Symposium

ORGANISED by a joint committee representing the Institute of Welding, the British Welding Research Association, the Institution of Naval Architects, the British Shipbuilding Association and the Aluminium Development Association, a Symposium on the Use and Welding of Aluminium in Shipbuilding will be held in the Weir Lecture Hall of the Institution of Naval Architects, 10 Upper Belgrave Street, London, S.W.1., on the 7th and 8th December, 1955. Some 22 papers will be presented; the first session dealing with welding processes and techniques; the second with materials and design; the third with applications; and the fourth with applications and economic factors.

Blast Furnace Record

DURING the week ending October 2nd, Europe's largest blast furnace, the Queen Victoria at the Scunthorpe works of Appleby-Frodingham Steel Co., a branch of The United Steel Cos., Ltd., produced a world record output for lean iron ores of 11,160 tons of pig iron. Working entirely on low-grade British ores, averaging 20% iron content, it is believed that this achievement has not been equalled by larger American blast furnaces, which operate with ores containing 55% of iron. Queen Victoria's performance is also notable for marking the first occasion on which a British blast furnace has exceeded a five figure tonnage in one week. The previous record, set up by the same blast furnace earlier this year, was 9,130 tons.

The Appleby-Frodingham blast furnace plant, comprising the four "Iron Queens"—Mary, Bess, Anne and Victoria—together produced 27,280 tons of pig iron last week, which is in itself a record for the British steel industry. Still higher outputs are envisaged when a new turbo-blower, costing over £750,000 and the largest of its kind in the world, comes into service early in 1957.

Institute of Metal Finishing Officers

THE Institute of Metal Finishing announces that the Officers and Council for Session 31 (1955–56) are as follows:—

President: R. A. F. HAMMOND.

Immediate Past President: PROFESSOR J. W. CUTHBERTSON.

Vice Presidents: S. G. CLARKE, T. P. HOAR, L. B. HUNT, R. W. NICOL, H. SILMAN, A. SMART and A. W. WALLBANK.

Honorary Treasurer: F. L. JAMES.

Honorary Secretary: S. WERNICK.

Members of Council: G. L. J. BAILEY, W. F. B. BAKER, J. E. GARSIDE, A. A. B. HARVEY, D. N. LAYTON, L. MABLE, R. T. F. McMANUS, C. WHARRAD and F. WILD.

Ex-Officio: E. E. LONGHURST (Chairman, London Branch), L. MABLE (Chairman, Midland Branch), W. A. BOWKER (Chairman, Sheffield & North-East Branch), S. A. J. MURRAY (Chairman, Scottish Branch), and W. STEIN (Chairman, Organic Finishing Group).

International Stud Welding Conference

AT the invitation of the Stud Welding Organisation of Crompton Parkinson, Ltd., the leading stud welding interests of fifteen overseas countries sent representatives to London recently to review development and research experience gained since the previous meeting in Paris in September, 1953. The meetings in London were followed by a visit to the Crompton Parkinson stud welding factory in South Wales where technical discussions were continued on improved methods and processing of the well known Nelson and Cyc-Arc studs.

One of the most interesting conclusions reached by the conference was in regard to the future field for stud welding. Originally, this system had been regarded simply as a more economical and faster alternative to conventional drilling and tapping. More recently, it had begun to find new fields of applications, particularly in steel and reinforced structures. Another interesting feature was the emphasis placed on the importance of introducing mechanisation into workshop stud welding

by means of indexing fixtures, and also automatic feeding of studs through the stud welding tool.

The conference concluded by an inspection of the new Velindre cold reduction mills of the Steel Company of Wales, where stud welding has been used to overcome the problem of highly fatigue stressed fastenings of crane rails to girder structures. In this application a stud welding power source comprising Crompton Parkinson type batteries was used, instead of running a heavy-duty three-phase supply from the nearest substation. A fully automatic charging circuit ensures that the batteries are rapidly recharged to a predetermined voltage level before each stud welding operation.

New Melting Furnace Development

It is announced that Birlec Ltd., has concluded an arrangement with Otto Junker G.M.B.H. of Lammersdorf, Germany, and the Ajax Engineering Corporation of Trenton, New Jersey, U.S.A., for the development and marketing of the mains frequency coreless induction melting furnace. This type of furnace, which is widely applicable to both ferrous and non-ferrous melting, including light metals and alloys, has been pioneered over a number of years in Germany by Junker, who have made over 80 installations, totalling some 30,000 kW. More recently, in England, Birlec began development work in the same field and has a prototype unit in industrial use. By pooling the technical resources and experience of these three well-known companies in the induction furnace field, a valuable contribution to melting practice becomes available to the metallurgical industries throughout the world. This important addition to the well-known range of Birlec melting furnaces enables the Company to recommend and supply the most suitable equipment for any kind of metal-melting application.

British Oxygen Chemicals Ltd.

The British Oxygen Co., Ltd., have announced that their Chemicals Division has been brought under a new subsidiary company known as British Oxygen Chemicals, Ltd. The objects of the new company are to manufacture and sell chemical derivatives of carbide of calcium, acetylene, nitrogen, oxygen, etc. The authorised capital is £1,500,000, which will be divided into 1,500,000 shares of £1 each, and the directors are Mr. F. C. S. L. Lewin-Harris and Dr. R. F. Goldstein.

Visits to Elecfurn Works

During recent winters, Wild-Barfield Electric Furnaces, Ltd., have extended to organised parties of members of engineering societies, technical colleges, and the like, an invitation to visit their works at Watford. Such visits have apparently proved interesting, for some organisations have taken advantage of the invitation in successive seasons. The Company regrets, therefore, that for the 1955–56 season the arrangements have had to be suspended, as major extensions to the premises are in progress. Various departments hitherto housed in temporary buildings have of necessity been transferred to other parts during the building operations, and there is considerable congestion and dislocation of the normal manufacturing sequence. It is not possible under such circumstances to arrange a satisfactory tour of all departments as the Company would wish, and the arrangements have, therefore, been deferred until order is restored.

Personal News

Vickers-Armstrongs, Ltd., announce the following changes in organisation. Mr. W. D. Opher, at present a Director of Vickers-Armstrongs (Engineers), Ltd., and General Manager of the North Eastern Works of that Company, will join the Boards of the Parent Company, Vickers-Armstrongs, Ltd., and of Vickers-Armstrongs (Shipbuilders), Ltd.—he will take over the office of Deputy Managing Director of Vickers-Armstrongs (Engineers), Ltd., and General Manager of the Barrow Works, in place of Mr. F. P. Laurens; Mr. A. P. Wickens will assume the office of General Manager of the North Eastern Works of Vickers-Armstrongs (Engineers), Ltd.; Mr. J. R. Hendin will be Manager, Industrial Tractors, Scotswood Works of Vickers-Armstrongs (Engineers), Ltd., in place of Mr. Wickens; and Mr. R. Wonfor is appointed a Special Director of Vickers-Armstrongs (Engineers), Ltd., on taking over the duties of Mr. Hendin as Joint Manager, Engineering Sales Departments.

Mr. V. Young has been appointed Chairman of International Combustion, Ltd., and Mr. W. Grainger and Mr. J. Mayer, who were recently appointed Joint Managing Directors of International Combustion (Holdings), Ltd., have also been appointed Joint Managing Directors of International Combustion, Ltd.

Lt.-General Sir Ronald Weeks, K.C.B., C.B.E., D.S.O., M.C., T.D. (Chairman of Vickers, Ltd.), has relinquished the office of Chairman of English Steel Corporation, Ltd. He is succeeded by Mr. F. Pickworth who has also joined the Board of Vickers, Ltd. Mr. W. D. Pugh succeeds Mr. Pickworth as Managing Director of English Steel Corporation, Ltd.

Barlow-Whitney, Ltd., announce that Mr. J. T. Sharples, until recently Manager of the Company's Northern Area Branch, has been appointed Manager of the main plant at Bletchley, Bucks. Mr. Sharples is succeeded as District Manager by Mr. G. H. Toller.

Birmid Industries, Ltd., announce that the following have been appointed to the Board of the Company: Mr. J. W. Berry, Joint Managing Director, Birmingham Aluminium Casting (1903) Co., Ltd.; Mr. H. Goodwin, Joint Managing Director, Birmetals, Ltd.; Mr. G. A. Rider, Commercial Director, Birmingham Aluminium Casting (1903) Co., Ltd.

Mr. L. G. Earle, until recently Manager of Capper Pass & Son's Melton Works, has joined Campbell, Gifford & Morton, Ltd., of Weybridge, as a Director.

Mr. F. Kendrick, Works Manager of the Sheffield Forge & Rolling Mills Co., Ltd. (a member of the Darwins Group), who has been with the Company for 53 years, has been appointed to the Board.

Sir Eric Bourne Bentinck Speed, K.C.B., K.B.E., M.C., has been appointed to the British Board of Engelhard Industries, Ltd., of 52, High Holborn, London, W.C.1.

Dr. W. Steven has been appointed Superintendent of

the Development and Research Laboratory of The Mond Nickel Co., Ltd., in Birmingham, in succession to the late MR. HOWARD EVANS. Dr. Steven joined the Development and Research Department in July, 1947, and was appointed Principal Assistant to the Superintendent in May, 1954.

MR. G. A. PLUMMER has been appointed to the main Board of John Thompson, Ltd. He will continue as a Director and Chief Engineer of John Thompson Water Tube Boilers, Ltd.

MR. G. D. MOLE has joined the staff of Smiths Aircraft Instruments, Ltd., as a Project Engineer (Engines). His previous appointment was with Rolls-Royce, Ltd., as Personal Assistant to the Chief Executive.

PROFESSOR P. M. S. BLACKETT, F.R.S., Professor of Physics in the Imperial College of Science and Technology, and MR. H. DOUGLASS, General Secretary of the Iron and Steel Trades Confederation, have been appointed members of the Advisory Council for Scientific and Industrial Research.

MR. J. E. ROBERTS, Buyer in the Purchasing Department of Steel, Peech & Tozer, Rotherham, a Branch of The United Steel Cos., Ltd., has retired after 43 years' service. He will be succeeded by MR. F. RODGERS, who has been Assistant Buyer for some time.

MR. F. W. SWINNEY, General Manager of the Furnace Division of The International Furnace Equipment Co., Ltd., of Aldridge, Staffs., has been appointed a Director of the Company.

MR. R. C. PERRITON, formerly a Liaison Officer with the British Non-Ferrous Metals Research Association, has been awarded a King George VI Memorial Fellowship for 1955/56 and is studying Industrial Administration at the University of California.

MR. O. H. FISH, former Dealer Sales Manager of the Regent Oil Co., Ltd., has been appointed General Sales Manager. MR. R. A. MUNRO has been appointed Assistant Sales Manager, and will be responsible for Dealer Sales Development, and MR. G. L. MACNAGHTEN takes over Mr. Munro's appointment as Manager, Sales Promotion Department.

Obituary

We regret to record the deaths of the following :—

MR. HOWARD EVANS, Superintendent of the Research Laboratory of The Mond Nickel Co., Ltd., Birmingham, who died suddenly on Sunday, 11th September. Mr. Evans left the Research Department of Metropolitan-Vickers Electrical Co., Ltd., in 1938 to join the Development and Research Department of The Mond Nickel Co., Ltd., as Research Metallurgist in their Birmingham Laboratory. In 1945, he was appointed Principal Assistant to the Superintendent, and in May, 1954, Superintendent of the Laboratory. During the year 1954/55, he was President of the Birmingham Metallurgical Society.

ALDERMAN H. A. CRUSE, C.B.E., Director of Westinghouse Brake & Signal Co., Ltd., who died on 18th September. Alderman Cruse retired from his executive post as General Works Manager on December 3rd, 1954, after 53 years' service with the Company. He had a great record of public service to the Borough of Chippenham, where he was Mayor for three years. He also served several terms of office as President of the Engineering and Allied Employers West of England Association.

MR. C. A. SCOTT, for many years Chief Erection Engineer of EFCO, Ltd., who died suddenly on Saturday, 17th September.

The British Cast Iron Research Association

(*continued from page* 177)

cast irons for carbon determination has been reported and a rapid method for the determination of magnesium has been developed and successfully applied. Other work has included the determination of phosphorus in cast iron (406); more rapid methods of slag analysis; and the determination of pitch in moulding sand. The application of spectrographic methods to slag analysis has continued. Fig. 6 shows the three units of the quantometer on the right—recording console, source unit and grating spectrometer; and on the left the grating spectrometer for research purposes.

Work on malleable cast iron has covered the production of sound malleable iron test bars and an analysis of the reproducibility of properties in various malleable foundries using several methods of running and feeding test bars. Other work has been concerned with the influence of graphitization on rate of decarburization, and the influence of atmosphere composition on sulphur penetration during annealing.

Reports have been issued on the influence of surface rolling on the fatigue of flake and nodular graphite cast irons (392); on the influence of annealing temperature on ductility and brittleness of ferritic nodular cast irons; and on a series of fatigue tests on hardened and tempered nodular irons (404). Much work has been done on the influence of under-stressing and over-stressing on the fatigue properties of nodular cast iron, and a study of the stress/strain curve in tension for nodular cast irons has been made.

An investigation of the influence of trace elements on the high-temperature properties of pearlitic nodular cast iron has shown that various trace elements have a profound effect on mechanical properties at 400°–600° C. Data are being collected on the use of cast iron in steam engineering with the object of encouraging its use above the present limit of 450° F.

The British Welding Research Association

(*continued from page* 190).

Charpy transition temperature, a running crack may be brittle before being arrested. Further tests on 1-in. thick plates with longitudinal butt welds and central crack initiation are under way. Initial tests showed that a small crack may propagate in a residual stress field with very small or no external load, but complete fracture only occurred at a larger load. Complete fracture did not occur in the specimens which spontaneously cracked until general yield developed across the full plate width.

Non-Destructive Testing

Progress has been made in the development of techniques for the ultrasonic standard reference block which will facilitate the adjustment of ultrasonic equipment and enable conditions of testing to be standardised. Work on the revision of document T.29—Memorandum on Non-Destructive Methods for the Examination of Welds has made good progress, and it is hoped that the revised version will be available early next year.

RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

Flexible Couplings

Crofts (Engineers) Ltd., announce the addition of three new designs to their range of flexible couplings. The Block type (sandwich unit construction) is suitable for drives up to 1,750 h.p./100 r.p.m. It possesses maximum torsional resilience to absorb shock loads and damp out fluctuating torques or oscillations, so providing adequate protection for both driving and driven machinery against transmitted shock and vibration. The predominant feature of the coupling is the degree of resilience obtained through the large volume of special quality oil resisting rubber incorporated in the design, which also accounts for the coupling's ability to accommodate angular and lateral misalignment without imposing undue bending stresses in the shafts or excessive loading of shaft bearings. The resilient or flexible member of this coupling is embodied in a self-contained sandwich unit which can be removed from the driving and driven coupling flanges without disturbing shafts, bearings, etc. The design also permits lateral float of the shafts and prevents the transmission of end thrust from driving to driven shaft, or vice versa, and so effectively eliminates wear of shaft bearings.

The Uniflex type (sandwich type construction) is of all metal construction, with power being transmitted through metal membranes which will withstand a wide degree of flexing ; these are not affected by operating temperatures or atmospheric conditions. The construction of the coupling consists essentially of driving and driven halves, fitted with driving pins, inner and outer clamp plates, and the flexible membranes. The sandwich form of construction permits easy fitting or removal of the transmission unit without disturbing either the driving or driven halves of the coupling. A further feature is the freedom from backlash even under extreme conditions of loading. The driving pins being extended into free holes in the opposing half coupling ensures continuity of the drive in the event of the failure of the laminates, due to unforseen shock loading. This type is suitable for drives up to 450 h.p./100 r.p.m.

The NT Internal Gear Flexible Coupling is a redesigned version of the MB Sleeve Series of geared type couplings, possessing many similarities to the earlier type, but employing a principle of simplified construction which eliminates the flanges, bolts and nuts, and provides a positive sealing arrangement, thus reducing the diameter and weight for a given horsepower. Steel snap springs are incorporated to locate the outer sleeve, and the NT can be uncoupled and reassembled in a few seconds. The mating internal and external gears provide even distribution of the load over all the teeth, while the construction of the coupling effectively compensates for axial and angular misalignment of the shafts and end float. The NT is available in sizes suitable for drives up to 800 h.p./100 r.p.m.

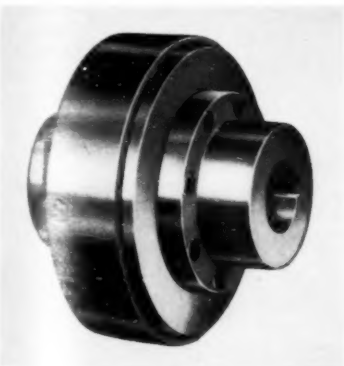
Crofts (Engineers), Ltd., Bradford, 3.

Seam Welder

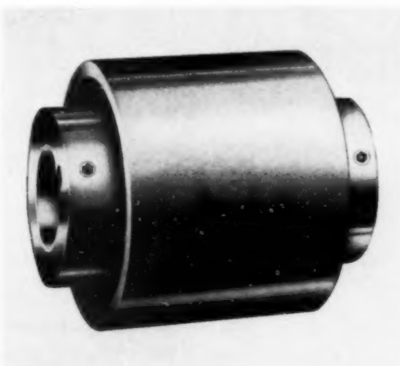
Philips Electrical, Ltd., have recently added to their range of resistance welding equipment a universal seam welder known as the ES.2003 series. With outputs ranging from 75 to 200 kVA., and throat depths of 24 in., 32 in., or 42 in., it is a versatile machine suitable for most types of mild steel and refractory alloys. Welding capacities are up to 2×14 s.w.g.

The plant can be used for circumferential or longitudinal welding, change-over being simply accomplished by turning the upper wheel assembly through 90° and replacing the lower assembly. A distinctive feature of the plant is that current pick-up for this lower wheel is through a segmental commutator. This allows the wheel to run on non-conducting needle roller bearings, with a consequent increase in bearing life. Drive to the upper wheel is through a shaft from a 3-phase motor. Speeds are infinitely variable from 3 to 15 ft./min., and reverse. The lower arm can be adjusted vertically by means of a hydraulic jack, maximum height variation being 9 in. Normally, components with a minimum diameter of 7¾ in. can be welded, but special arm arrangements can be supplied for individual requirements.

The machine is fully air-operated, and auxiliary equipment is fitted to ensure that only clean dry air is used. Welding pressure is supplied by an air cylinder,



Block type



NT type

Uniflex type

the assembly of which contains a dynometric pressure switch to prevent a weld being initiated before correct pressure has been reached. The machine is controlled by a Philips P.5014/32 Tempomat, incorporating phase-shift heat control, ignitron contactor and a synchronous timer.

Philips Electrical, Ltd., Century House, Shaftesbury Avenue, London, W.C. 2

Press Indexing Table

THE features aimed at in the design of this Mills' Oilaulic unit were robustness and rapid and accurate indexing. Being primarily intended for use on presses developing up to 45 tons, ample contact area is provided under the working station. To allow easy and rapid rotation, the contact surfaces are separated by a spring resting on a ball which, except when working loads are applied, acts as a thrust bearing to take the weight of table and tooling with very little friction, while under load the spring yields allowing the table to rest solidly on the cast iron housing.

The table is a solid disc 2¾ in. thick driven by a hydraulic motor. Sunk in accurately spaced recesses under the table are taper ground sockets for the index plunger, which works in a steel sleeve mounted in the housing. The plunger is engaged by a spring and withdrawn by a hydraulic ram which also functions as a piston valve, admitting oil to the motor only when the index plunger is fully disengaged.

Corresponding to each station on the table there is a cam on the periphery so placed that as the index point is approached the cam acts on a roller on the main valve, depressing it so that the catch engages. In this position oil is released from the index withdraw ram, allowing the index plunger to bear on the underside of the table. At the same time the motor exhaust is made to pass through an adjustable orifice, checking the speed of the table so that when the index point is reached, engagement takes place without shock—an important feature for the preservation of accuracy. When fitted on a hydraulic press the pressure supply to operate the table can usually be taken from the pump powering the press. On other applications a small motor-pump unit is used, connected by flexible pipes.

In the normal application on a press, it is the return of the press ram which trips the catch to initiate indexing, but any motion of a machine tool can be used in the same way, and interlocking is provided to prevent operation of the machine tool except when the index plunger is engaged. To allow more time for loading or re-assembly on the table, the sequence can be arranged to be initiated by indexing, followed automatically by the machine tool operation, during which loading can be carried on. When automatic loading is applied, the sequence can be repeated automatically, giving continuous running.

In the standard size the working surface of the table is 24 in. diameter, the station centres being on a 16 in. diameter. Any number of stations up to 12 can be provided, and stations can be selected by setting the cams. An automatic ejector can be fitted if required.

John Mills & Co. (Llanidloes), Ltd., Railway Foundry, Llanidloes, Mont.

High Speed Mild Steel Electrode

THE QUASI-ARC CO., LTD., manufacturers and suppliers of electrodes, plant and accessories for electric arc welding, announce that they have now added to their wide range of arc welding electrodes the Zodian electrode for high speed production welding of mild steel. The smooth arc characteristics and the ease of slag detachability, combined with the ability of Zodian electrodes to carry high welding currents, make them particularly suitable for economical high speed welding in general engineering and shipbuilding. 12 s.w.g. and 10 s.w.g. rods are being used at high welding currents in the mass production of components for the automobile industry and for other light sheet metal work. Zodian electrodes are made in sizes 16 s.w.g. to $\frac{5}{16}$ in. diameter. Another outstanding feature of these electrodes is their suitability for welding joints with a poor plate fit-up and for welding on rusty plate.

Zodian electrodes comply with B.S.639 : 1952 and have the Code No. E217 to B.S.1719 : 1951 classification. They are approved by Ministry of Transport and Civil Aviation, Lloyd's Register of Shipping and Det Norske Veritas for welding mild steel in all positions, also by the Inspectorate of Electrical and Mechanical Equipment, Ministry of Supply, for welding mild steel components for which they are the inspecting authority. Other approvals are pending.

The Quasi-Arc Co., Ltd., Bilston, Staffordshire.

Morris to Make U.S. Polishing Equipment

B. O. MORRIS, LTD., have concluded an agreement with Hammond Machinery Builders, Ltd., of Kalamazoo, Michigan, U.S.A., to manufacture their automatic and semi-automatic polishing equipment, including rotary and straight line machines, under licence in this country. Production of the range of machines has commenced.

LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS

OCTOBER, 1955 Vol. LII, No. 312

Progressive Etching Effects on a Selected Area of Pearlitic Steel Revealed by the Electron Microscope

By D. E. Bradley

Research Laboratory, Associated Electrical Industries Ltd., Aldermaston.

The electron microscope study of a selected area of pearlitic steel at intervals during etching gives a clear picture of the manner in which the etchant attacks the specimen. The results obtained also give some information as to the nature of the worked layer produced by the initial polishing.

IN the preparation of metallurgical specimens for examination by the electron microscope, the use of the most suitable etchants and etching times is of the greatest importance. In this paper, the effect of varying the etching time on a pearlitic structure is examined. By observing the structure in a selected field of the specimen at successive stages during the etching process, it is possible, not only to determine the most suitable etching time for the type of steel used, but also to gain some information concerning the mechanism of etching.

Method

In order to obtain an accurate picture of the etching process, it is essential to be able to examine a selected field in the electron microscope. This can be achieved satisfactorily by preparing carbon replicas[1], which possess a number of advantages. It is necessary to use a modification of the existing technique, but, since the method is described in detail elsewhere[2], only an outline of the process will be given here.

The carbon replica is made in two stages. Firstly, a preliminary impression, consisting of a thin film of Formvar, is formed on the metal by flooding the surface with a solution of the plastic in a mixture of chloroform and dioxane, and allowing the solvents to evaporate. By means of a simple attachment to a 16 mm. optical microscope objective, a centre-marked electron microscope specimen support grid can be positioned on the surface of the specimen with the area of interest in a grid square near the centre mark. The attachment holds the grid in position while a few drops of 1–2% Bedacryl* in ether are applied. The ether is dried in a stream of cold air, leaving a Bedacryl film anchoring the grid to the Formvar film on the specimen. The grid is then removed from the metal surface with the Formvar impression firmly attached to it by the Bedacryl. A thin layer of carbon is then evaporated[3] onto the Formvar, which is finally washed away, together with the Bedacryl, by flowing chloroform over the grid from a burette. The carbon replica remains anchored in its position on the grid, probably by a small amount of undissolved plastic behind the grid bars. It is now ready for shadowing and examination in the electron microscope.

The steel specimen used, reference number CAD4, was supplied by the British Iron and Steel Research Association. The main constituents were carbon, 0·52%, silicon, 0·26%, and manganese, 0·81%, and the metal was annealed at 950° C. and then furnace cooled. The surface was prepared by grinding in the usual manner, and polishing on coarse, then fine, diamond dust. The specimen was then etched for 30 seconds in 2% nital and repolished. This treatment was followed by two 10 second etches in 2% nital, each removed by polishing. A weak etchant, ¼% nital, was used for the experimental treatment so that the etching time in each stage could be gauged accurately. A selected area was examined by the electron microscope after 20, 40, 60 and 80 seconds etching treatment.

Results

Fig. 1 shows micrographs of the same area after it had been treated as described. In Fig. 1*a*, a great deal of debris is present, and the carbide lamellae are barely distinguishable. The presence of this debris suggests that the worked layer produced by the polishing consists of flowed ferrite with the remains of broken carbide lamellae embedded in it. It can be seen from Fig. 1*b* that a further 20 seconds etch removed most of the ferrite and released the greater part of the carbide particles. Complete removal of the debris is not achieved until the full 80 seconds etch has been carried out. By comparing Figs. 1*c* and 1*d*, further interesting points can be noted. The point marked *A* on the carbide particle shown in Fig. 1*c* appears to have undergone a definite chemical attack during the last 20 seconds etching, since, in Fig. 1*d*, where it is marked *A′*, it has been almost completely removed. In fact, the entire carbide particle has been reduced in size. The behaviour can also be seen in the particle marked *B* and *B′*. This definite but slight chemical attack on iron carbide by nital is unexpected. Though a great deal of work has been carried out on

* Bedacryl is an extremely soluble resin made by I.C.I. Ltd.

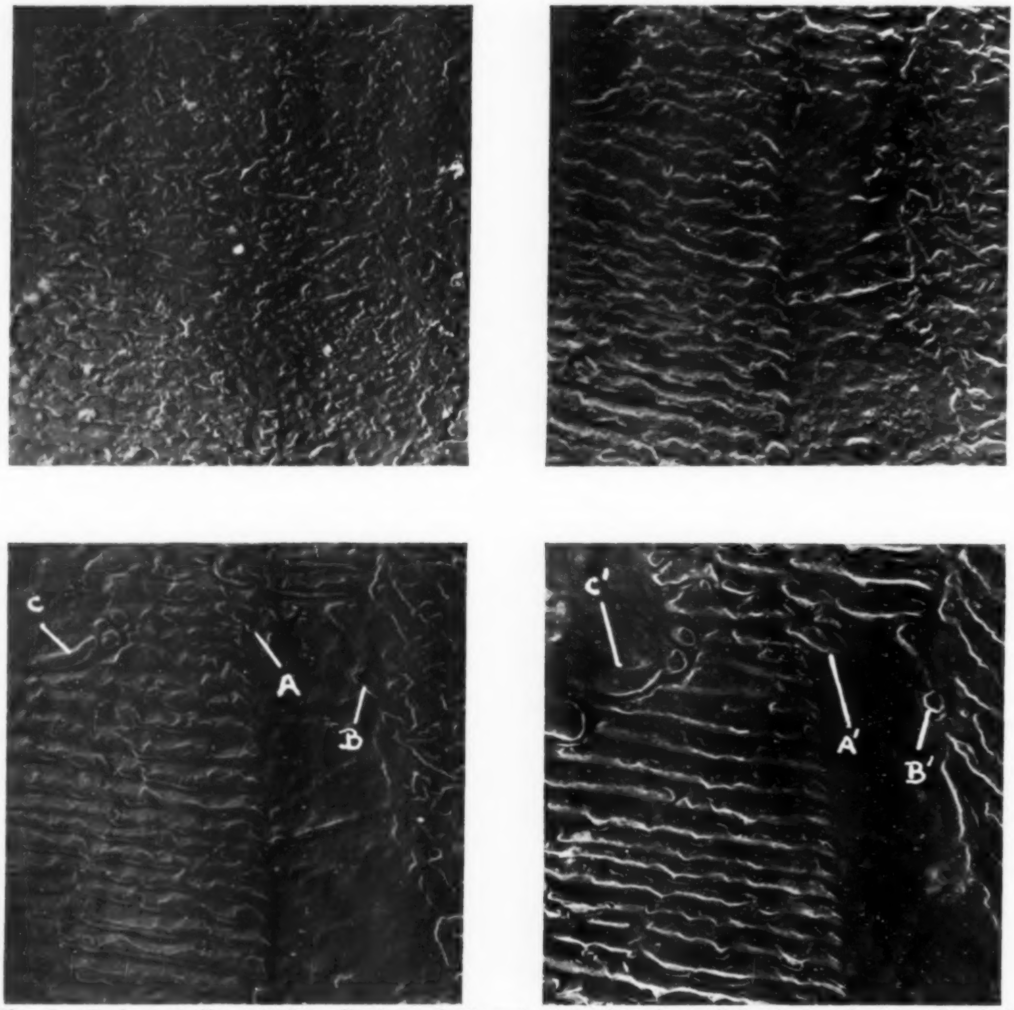


Fig. 1.—Carbon replicas (gold-palladium shadowed at $\tan^{-1}\frac{1}{2}$) of pearlitic steel etched in $\frac{1}{2}$% nital for (a) 20 seconds, (b) 40 seconds, (c) 60 seconds, (d) 80 seconds. ×12,000

pearlitic structures, using the electron microscope, this is the first time that a given particle of iron carbide has been observed during progressive etching. Because the amount of carbide dissolved away from the lamellae is small, it would not be detectable by the study of different fields or particles.

If the particle at C and C' is examined, contrary to the previous observation, a marked increase in size is noted. This is because, as the matrix is dissolved, more and more of the particle is revealed, since it enters the ferrite at an angle. This effect will not be apparent when the walls of the particle are perpendicular to the matrix. It can also be seen that the surface of the large ferrite grain becomes smoother as etching proceeds. This may be because the ferrite was protected from chemical attack in the regions beneath the carbide debris until this was removed, thus causing an initial unevenness which would be smoothed out later.

Conclusions

Much can be learned about the mechanism of etching by using a technique for examining selected areas in the electron microscope. The method described is very simple and quick. Several other techniques have been devised[4,5,6], but these are more complicated, and are not suitable for use with carbon replicas, which give improved resolution and are easy to produce. The micrographs show that any etching technique can be readily followed. The method would also be valuable in the study of the formation of slip lines, and in many other fields. In addition, it is often of great value in metallurgy to be able to correlate electron microscope results with those obtained with the optical microscope.

Acknowledgments

The author wishes to thank Mr. M. E. Haine, Dr. N. C. Welsh and Dr. J. E. Hughes for their help and suggestions and Dr. T. E. Allibone, F.R.S., Director of this Laboratory, for permission to publish this note.

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Non-Destructive Metallography of Plain Carbon Steels

By K. Sachs,* and J. D. Bunton†

The use of chemical polishing of the surface of heat treated components enables the effectiveness of the heat treatment to be checked with greater certainty than by other means. It also reduces the more tedious work of specimen preparation, eases the pressure of routine inspection, and, by increasing the size of the sample used for control, enhances the reliability of control and the quality of the product.

THE control of the bulk heat treatment of small components, and of flame or induction hardening, presents numerous problems. The effectiveness of the heat treatment is generally checked by hardness tests on samples from a batch, nor on a few points on the hardened surface. Unfortunately, the hardness test is not sensitive to grain size, nor to the presence in small quantities of undesirable microconstituents, which may have a profound influence on other mechanical properties and on the usefulness of the component in service. It is frequently found necessary, therefore, to select a few samples for destructive tests of mechanical properties or for microscopic examination. Even with large components, like driving sprockets for caterpillar tracks, slew gears or bearing races for horizontally revolving structures, etc., it is often the practice to cut up a small number of samples from each batch for detailed examination.

In recent years, non-destructive testing of physical properties has made enormous strides, and the close relation between the coercive force and hardness is used for checking the effectiveness of heat treatment in a number of magnetic sorting devices; quite complex properties, such as the mean carbon content and depth of a carburized case can be controlled at extremely high speed by this means. These methods have serious limitations, however; like hardness tests, they are insensitive to grain size and the more subtle variations in microstructure, and many components are unsuitable for them owing to their size or geometry.

* G.K.N. Group Research Laboratory † Garringtons, Ltd.

In a wide field of applications, therefore, control of heat treatment must continue to depend on the examination of samples from each batch. The reliability of the results of such examination, the effectiveness of control, and, in the long run, the usefulness of the product and the good name of the producer, will depend on the size and representative nature of the sample used for such tests. On the other hand, the cost of production and, therefore, the price of the product and the competitive position of the producer, are profoundly influenced by the cost of inspection and control. This cost is related to the size of the sample for two reasons: (*a*) in a destructive test each tested component represents scrap; and (*b*) the larger the sample the higher will be the labour and overhead costs of preparing specimens and carrying out the inspection. Microscopic examination of the actual surface of the component after chemical polishing, involving a minimum of mechanical preparation, offers the double advantage of reducing the amount of tedious labour required and preserving the components for sale after examination. In this way the economic limit on the size of the sample can be raised considerably, the effectiveness of heat treatment or surface hardening can be more reliably controlled, and the final product can be offered for service with increased confidence.

Chemical Polishing

A solution for the non-electrolytic smoothing of steel was developed by Marshall in 1951[1]. It consists of 2·5g. oxalic acid, 1·3g. hydrogen peroxide, 0·01g. sulphuric acid and distilled water to a total volume

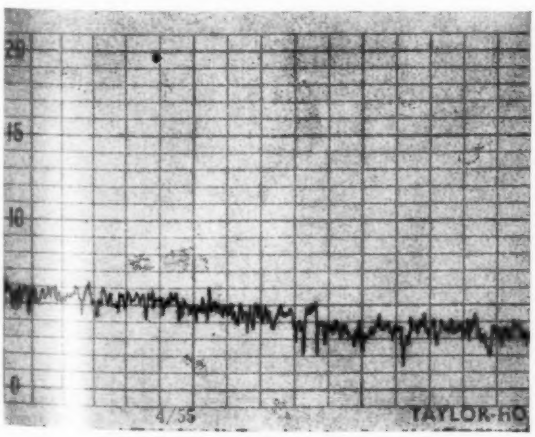

Fig. 1.—Talysurf trace of mild steel surface prepared on 600 grade emery paper. Magnification 20,000/100. C.L.A. 2·5μ in.

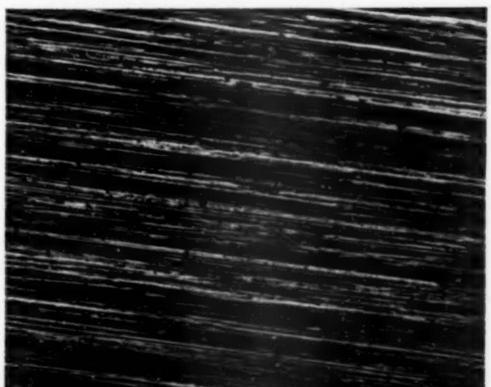

Fig. 2.—Photomicrograph of the surface referred to in Fig. 1. × 200

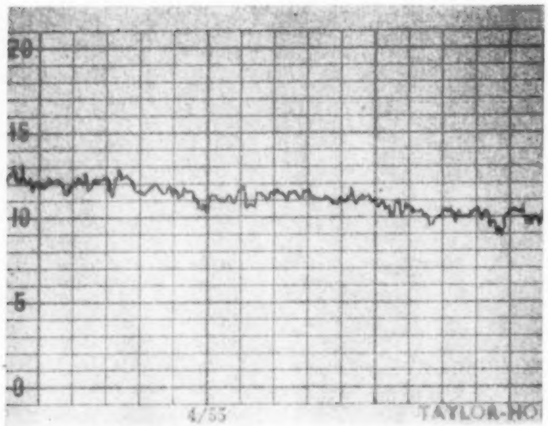

Fig. 3

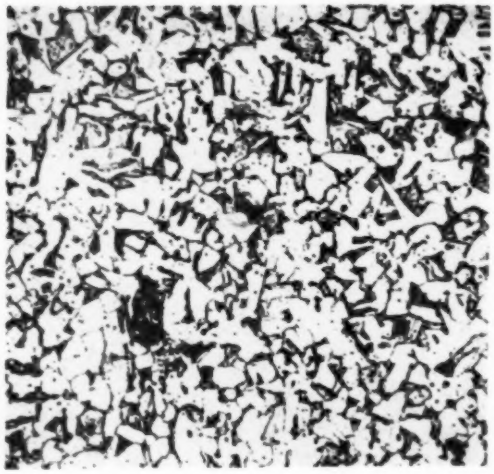

Fig. 4

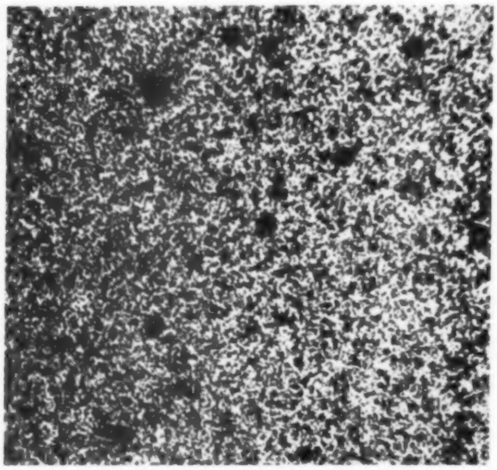

Fig. 5

Fig. 3.—Talysurf trace of the surface referred to in Fig. 1 after 5 minutes in Marshall's solution. Magnification 20,000/100. C.L.A. 3·0 μ in.

Fig. 4.—Photomicrograph of the surface referred to in Fig. 3. × 200

Fig. 5.—Silver steel, water quenched from 850° C. and tempered at 450° C. for 1 hour. × 200

Fig. 6.—Pearlite and ferrite in decarburised silver steel. × 200

Fig. 7.—Pearlite in decarburised silver steel. × 1,000

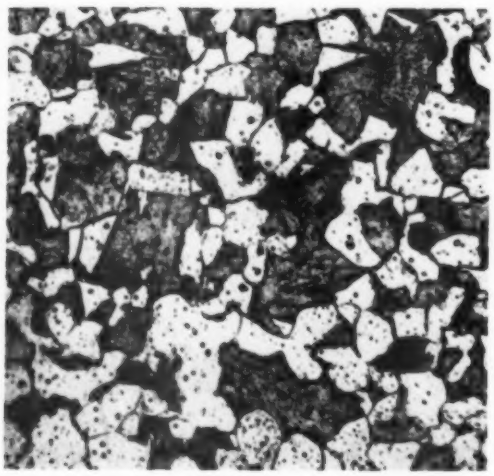

Fig. 6

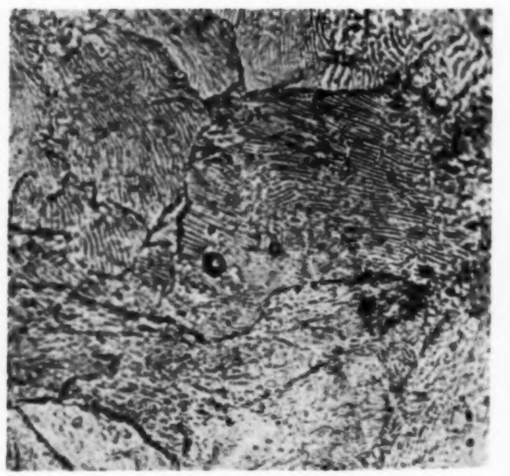

Fig. 7

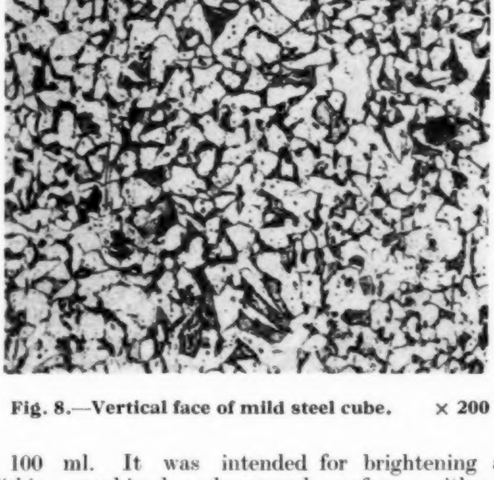

Fig. 8.—Vertical face of mild steel cube. × 200

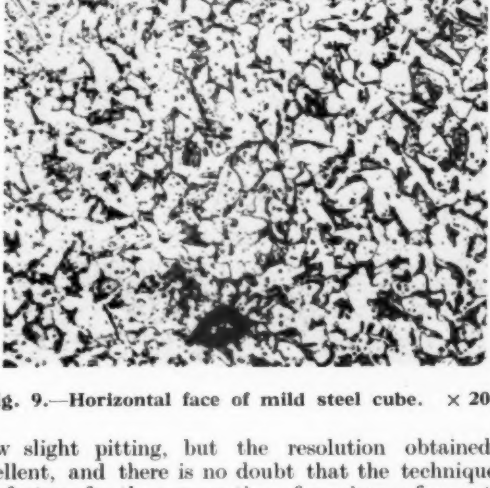

Fig. 9.—Horizontal face of mild steel cube. × 200

of 100 ml. It was intended for brightening and polishing machined and ground surfaces, either as a finishing operation or in preparation for electroplating. In the original paper the possibility of using the solution for simultaneously smoothing, without work-hardening, and etching steel samples for metallographic examination is briefly mentioned, and a few photomicrographs of mild steel surfaces are illustrated. A brief study of the appearance of various microstructures after polishing in a slightly modified solution has been reported by Graham, Cranston and Axon[2].

As there seemed little doubt that surfaces polished in Marshall's solution are suitable for micro-examination, an investigation of the usefulness of this solution for the preparation of microspecimens was undertaken by the G.K.N. Group Research Laboratory. Small specimens of mild steel ($\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2}$ in.) were ground down to 600 grade emery paper and immersed in the solution for various periods. The texture of the ground surface is illustrated in the Talysurf trace in Fig. 1, and in the photomicrograph in Fig. 2. After five minutes in Marshall's solution the surface has been polished and etched as shown in Figs. 3 and 4. The microstructure is clearly revealed and the scratches seem to have been smoothed out. However, the Talysurf trace shows that the surface is still very uneven, and there has been no decrease in the centre-line-average (i.e., the average deviation of the trace from a straight line drawn so that equal areas are included on both sides), although the sharpest irregularities have been removed and the wavelength of the surface roughness has been greatly increased.

A small specimen of silver steel in various conditions of heat treatment was polished in the same way. The sorbitic structure in Fig. 5 was produced by water quenching from 8[illegible] C. and tempering for one hour at 450° C. Figs. 6 and 7 show the structures near the surface and centre, respectively, of a specimen of silver steel decarburised by prolonged exposure at a high temperature in an atmosphere of moist hydrogen. The surfaces show slight pitting, but the resolution obtained is excellent, and there is no doubt that the technique is satisfactory for the preparation of specimens for routine examination.

Limitations of the Technique

The pitting observed in some of the specimens can be greatly reduced by immersing the specimen in such a way that the surface to be examined is not horizontal. The vertical and horizontal surfaces of a cube of mild steel polished in Marshall's solution for five minutes can be compared in Figs. 8 and 9. Both are reasonably satisfactory, but close examination reveals that the horizontal face is covered with tiny pits.

Unsatisfactory surfaces may be obtained due to severe over-etching if more than a very small amount of mineral acid is present in the solution, although there is evidence that a polish can be obtained again in the presence of substantial amounts of sulphuric acid. Severe pitting and ultimate roughening occurs if the solution

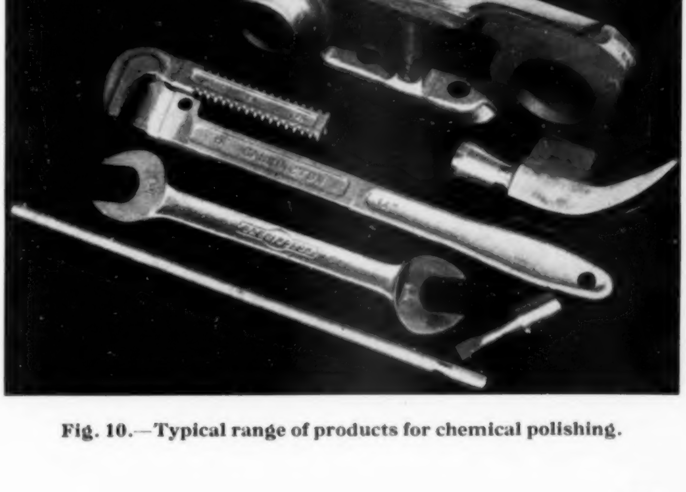

Fig. 10.—Typical range of products for chemical polishing.

TABLE I.—STEELS WHICH HAVE BEEN POLISHED WITH SOME DEGREE OF SUCCESS.

Designation	Composition						
	C%	Si%	Mn%	Cr%	Ni%	Mo%	V%
Mild Steel	0·08–0·35						
En.5C.	0·30–0·35	0·05–0·35	0·7–0·9				
En.8	0·30–0·45	0·05–0·35	0·6–1·1		0–1·0		
En.43B.	0·45–0·5	0·05–0·35	0·7–1·0				
En.9	0·50–0·6	0·05–0·035	0·5–0·8		0·5–0·8		
Silver Steel	1·0						
Carbon Steel[1]	1·13						
V10[1]	0·35–0·43	0·1–0·35	0·5–0·7	0·9–1·4	1·3–1·8	0·2–0·35	
V11[1]	0·22–0·35	0·3 max.	0·4–0·8	0·5–1·0	2·0–3·4	0·35–0·8	0·25 max.
En.39	0·12–0·18	0·1–0·35	0·5 max.	1·0–1·4	3·8–4·5		
Neor	2·3	0·6	0·4	13·0	0·6		
Malleable (White Heart) Cast Iron[1]							

is allowed to go stale for any reason. Ageing of the solution appears to depend on a number of factors, such as the volume of solution, the surface area immersed, and, probably, the degree of agitation and the temperature of the solution.

The time required to obtain a satisfactory polish depends on the initial surface; if the latter is too coarse, the solution may grow stale before polishing is complete, and the whole procedure becomes too time-consuming for practical purposes. In practice, a finely ground surface is adequate, and emery preparation finishing on grade 0 paper has been found suitable for works' laboratory routine.

The limits of composition within which satisfactory surface preparation is possible have not yet been defined with any accuracy. A list of steels which have been polished with some degree of success is given in Table I.

Practical Applications

The method has been adopted in the works laboratory of Garringtons, Ltd., for the routine examination of heat-treated forgings. The surfaces are generally polished down to grade 0 emery paper, but in some cases the ground finish has to suffice. Small components are treated in batches, with an additional saving of time. The immersion period varies between five and 30 minutes, according to the type of steel and the prior condition of the surface to be polished.

Typical products are illustrated in Fig. 10; in some cases the brightened zone can be distinguished in the photograph. Microscopic examination is particularly important for flame-hardened components, such as the hammer head, the adjustable wrench, and the track link in Fig. 10; temperature control during the flame hardening operation is much less reliable than in furnace heat treatment, and overheating may result in coarse grain size which cannot be detected by a hardness test, but which may lead to spalling of the hardened surface. Micro-examination of the flame-hardened zone, preferably on a face at right angles to the hardened surface, makes it possible to check the case depth, grain size, the microstructure of the case (to confirm that it is fully martensitic), and that of the core. It is not possible to

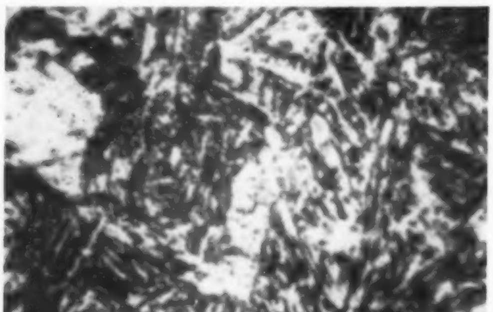

Fig. 11.—Tempered martensite. × 800

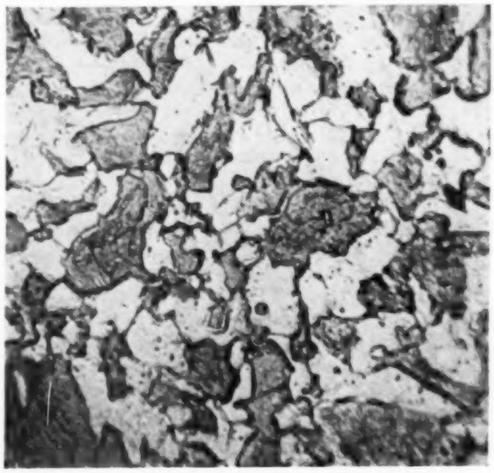

Fig. 12.—Ferrite and pearlite. × 300

carry out 100% inspection, except in the case of special orders, but the number of components examined has been increased considerably by the introduction of chemical polishing. In the past the shape of the components prevented micro-examination of the surface; only flat surfaces could be polished on a pad, and the flat end of a hammer head or a tommy bar could not be held on the pad. The track links are much too large to polish, and it was formerly necessary to cut them up for examination, which was laborious as well as wasteful. Such bulky components are now polished by making a wall of Plasticine to contain the solution. Track links are hardened and tempered prior to flame hardening of the wearing surface; the tempered martensite behind the flame-hardened surface is shown in Fig. 11. Examination of the core structure is also important; the toughness of the wrench and the shock resistance of the hammer head are a guarantee against brittle fracture in service. The normalized structure in the body of the

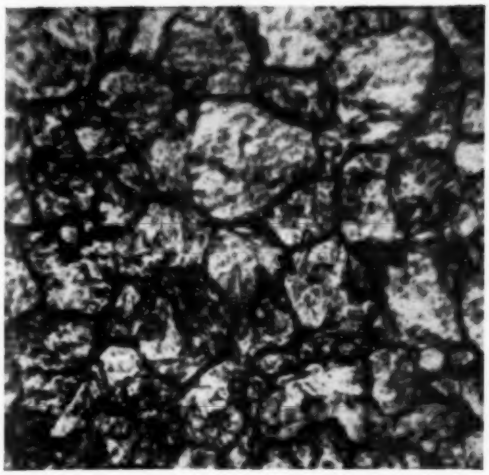

Fig. 13.—Martensite and troostite. × 800

wrench, away from the flame-hardened jaws, is illustrated in Fig. 12.

Although accurate temperature control in a closed furnace is a normal feature of heat treatment practice, full control of the process requires inspection of selected samples from each batch. The spanner, SKUA- bit, and tommy bar in Fig. 10 are representative of fully hardened and tempered components which are subjected to micro-examination after chemical polishing. One imperfection which can be detected by this method is slight surface decarburisation. Heavy decarburisation resulting in the appearance of free ferrite in the structure could be shown up by hardness tests, but in many cases the drop in carbon content is less pronounced and correspondingly less easy to detect. Its only effect is to move the S-curve to the left, i.e., in the direction of more rapid transformation, so that incipient transformation occurs in the decarburized zone during the quench. Troostite will form in the grain boundaries of the austenite and will be present in the final quenched structure when the remainder of the austenite has formed martensite. Fig. 13 shows such a structure ; the amount of troostite is too small to affect the hardness test. This type of partial transformation may occur in flame hardening, too, and routine micro-examination of flame-hardened surfaces will include a check for the absence of troostite.

The benefits of introducing chemical polishing in the works' laboratory can be summarised as a reduction of the more tedious work of specimen preparation, an easing of the pressure of routine inspection, and, most important, an increase in the size of the sample used for the control of heat treatment, and a consequent enhancement of the reliability of control and the quality of the product.

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Identification of Atmospheric Impurities

A NEW method for identifying minute concentrations of impurities in the air has been developed by scientists of Battelle Institute, Columbus, Ohio. The method involves " longpath " infra-red spectrophotometry and has the advantage of being extremely sensitive and accurate. It is expected to be useful in air-pollution control studies, and in the monitoring of industrial plant atmospheres.

The Battelle procedure for detection and analysis of air contaminants is based on the principle that specific substances in the air absorb certain wavelengths of light. Light is absorbed in proportion to the amount of the impurity in the air. By projecting a beam of infra-red light through a 175-ft. gap of air and measuring the type and amounts of light absorbed, small concentrations of impurities can be analysed both qualitatively and quantitatively. This procedure has been described in a preliminary report written by Battelle workers James Tighe, Richard Engdahl, and John Center.

Another advantage of the infra-red method is its rapidity. Usually, long periods are required to collect air samples for chemical analysis. The Battelle process detects and identifies impurities in the air directly and instantaneously. Serious attempts to control air pollution have, until now, been handicapped at times for lack of quick, accurate methods for identifying contaminating substances.

The " longpath " infra-red method of identifying air contaminants has other possible uses. For instance, it might be utilized in research aimed at evaluating the hazards to humans and animals of crop-spray residues remaining in the air after the mass spraying of agricultural acreages with experimental chemicals. It could possibly also be applied to prospecting for petroleum and natural gas, since it is sensitive to extremely minute quantities of vapors arising from the ground. All of Battelle's experiments to date, however, have been in connection with the measuring of impurities in industrial and municipal atmospheres.

1956 Congress of Analytical Chemistry

PROFESSOR I. M. KOLTHOFF, President of the Analytical Section of the International Union of Pure and Applied Chemistry, has announced that the Congress on Analytical Chemistry to be held in Lisbon from 9th to 16th September, 1956, will be under the patronage of the International Union of Pure and Applied Chemistry. Prof. Fernando Pires de Lima, Minister of Education, has appointed Professor D. Antonio Pereira Forjaz to be President of the Organizing Committee. Arrangements for the meeting are in the hands of Prof. Pierre A. Laurent, Instituto Superior Tecnico, Avenida Rovisco Pais, Lisbon, Portugal. Inquiries regarding plans for the meeting should be directed to him. It is intended that the Congress cover broadly all aspects of analytical chemistry. Further details will be published as soon as they become available.

THE telephone number of the London Office of British Electro Metallurgical Company, A Division of Union Carbide, Ltd., has been changed to LEGation 5361–5.

The Effect of Some Sample Forms on the Reproducibility of Spectrographic Analysis of Certain Magnesium Alloys Using Pin Electrodes and a Simple Source Unit

By E. C. Mills, F.R.I.C. and S. E. Hermon

Research and Development Division—High Duty Alloys Ltd., Slough.

Pencil and disc type samples have been used in an investigation of the reproducibility of spectrographic analysis of magnesium alloys. Aluminium and zinc are the most "difficult" elements in this respect, particularly the former. The horizontal cast disc electrode probably offers the simplest alternative sample form to the cast pencil, and merits further consideration.

IN parallel with our investigations on aluminium alloys to assess the effects of sample form on the reproducibility of spectrographic analysis[1], similar work was carried out on certain magnesium alloys.

In the laboratories of High Duty Alloys, Ltd., cast pencil electrodes similar to those used for aluminium alloy analysis have been used for routine control for a number of years, the instrument being a Hilger Medium Quartz (E 498) or a Zeiss Q 24 spectrograph with a simple uncontrolled condensed spark source unit. The necessary magnesium alloy standards are cast under carefully controlled conditions using the 8-pin die introduced by Frommer[2]. The production samples for analysis are cast in a die of the same type, or in a 4-pin, J-shaped die. Because of this, we have always been interested in the cast pencil sample form, and in the possibility of using small diameter extruded rod as an alternative standard form for day to day calibration purposes. The present investigation, abstracts of which are given here, was confined to alloys coming within the following composition ranges.

Aluminium	7–11%
Zinc	up to 1·0%
Manganese	up to 0·4%
Silicon	up to 0·3%
Copper	up to 0·3%

For control purposes it is our normal practice to determine spectrographically all the above elements except aluminium, and to use at least triplicate sparking. The spectrographic analysis of aluminium has always given difficulty, and particular attention was therefore given to this problem.

Experimental Procedure

In view of the increasing attention being given to point to plane techniques, a limited number of comparative tests were carried out on two different disc sample forms, using a graphite counter electrode.

The following pin and disc forms were prepared, using alloys within the composition ranges shown above.

(1) Die-cast pencils made in the 8-pin Frommer type die. The diameter of the pencils was 6 mm. and the average length 70–80 mm.

(2) Die cast pencils made in the 4-pin "J"-type die. The diameter was 6 mm. and the average length was 90–100 mm.

(3) Extruded rod obtained by the extrusion, through a five-hole die, of a cast billet 35 mm. in diameter and 125 mm. long. Five lengths of usable rod, each 50–55 cm. long and 6·35 mm. diameter, were produced from a single billet.

(4) Pencils 22 cm. long and 6 mm. diameter were machined from the central region of a large horizontal block casting, specially fed to minimise segregation.

(5) Vertically cast, die-cast discs, 56 mm. in diameter and 6 mm. thick, made in a book type die with vertical feeding.

(6) Horizontally cast, die-cast discs, 55 mm. in diameter and 4 mm. thick, made in a block type die with central vertical feeding.

All the samples used in the investigation were produced under closely controlled conditions in the Experimental Foundry, and were subjected to radiographic, microscopic, chemical and extensive spectrographic examinations during manufacture. A Hilger Simple Condensed Spark Unit and a Hilger Medium Quartz Spectrograph (E 498) were used throughout, and operating conditions and techniques were carefully standardised. The pin samples were machined down accurately to 3 mm. diameter, with the ends carefully faced off flat, and were sparked as self electrodes. As far as the disc samples were concerned, on the basis of previous spectrographic and metallurgical evidence, the most homogeneous areas were selected for sparking. 6 mm. diameter high purity graphite rod, machined in the same manner as the metal pins or to a sharp point, was used as counter electrode.

Discussion of Results

In each test, the selected form was sparked 24 times, using a large number of specimens of the particular type. The per cent. standard deviations (coefficients of variation) were calculated on the percentage contents. The average reproducibilities from a series of tests, covering a number of alloy samples, each sparked on several plates, are given in Table I.

Examination of this table appears to indicate that, of the pin types of electrode, the cast pencils from an 8-pin die are most suitable, and are superior to the small diameter extruded rod. Pencils cut from the cast blocks, which by their mode of preparation were expected to be relatively free from segregation, shrinkage or air entrapment, were found to be the worst cast form.

With regard to discs, the horizontally cast disc is seen

TABLE I.

Sample Form	Reproducibility					
	Al%	Zn%	Mn%	Si%	Cu%	All Elements Except Cu
Cast Pencils (8-pin.)	1·96	2·78	3·78	3·49	3·72	3·00
Cast Pencils (4-pin.)	2·39	3·69	3·51	4·59	—	3·72
Pencils from Cast Block	3·09	7·61	3·77	3·97	—	4·61
Extruded Rod	2·56	5·70	5·08	4·50	—	4·46
Vertically Cast Discs	2·47	2·77	5·92	7·03	5·73	4·55
Horizontally Cast Discs	1·97	2·47	4·22	3·01	3·05	2·94

to be superior to the vertically cast disc, as was expected from radiographic examination, which showed that the choice of sparking position was extremely critical with the latter disc form.

Comparing the extruded rod and pin samples of cast material, marked differences in element line ratios were obtained for manganese, although the other elements showed only slight divergences (within experimental error). This effect on manganese was unusual as, in aluminium alloy analysis, manganese was found to be the element least susceptible to source unit and sample form changes. The difference in ratios for manganese was persistent even when the simple source unit was replaced by the more powerful, Walsh G.P. unit. The following figures for the element line ratio are typical :—

	Simple Unit	Walsh G.P. Unit (20 μF, 12 ohms, 0·03 mH)
Extruded Rod	2·90	2·51
Cast Forms	3·54	2·78

The various sample forms were analysed chemically and found to have identical manganese contents.

In reviewing the results for the cast pencils, it must be remembered that these are obtained on restricted lengths (approximately 3 cm.) of carefully prepared pencils of similar length. Such use greatly reduces the life and economy of the standards and presents certain difficulties with routine control samples.

Outside the restricted region used, the metal was heterogeneous. This heterogeneity was most pronounced with aluminium and, to a lesser extent, with zinc. Manganese, copper and silicon were unaffected. Aluminium and zinc were determined along the full lengths of a selection of bad pencils, and Table II gives maximum and minimum figures obtained for these two elements over the total uncropped length of a pencil.

As a general rule, the part of the pencil remote from the spectro-base shows the greatest variation in composition, and the longer the pencil the more pronounced is its heterogeneity. The region selected for analysis was always the base end of the pencil, about 1–2 cm. from the root.

TABLE II.

Identification	Chemical Analysis		Spectrographic Analysis Range found through Pencil			
	Aluminium	Zinc	Aluminium		Zinc	
	%	%	Min. %	Max. %	Min. %	Max. %
SP	7·19	0·90	6·83	7·24	0·90	0·95
			7·13	7·54	0·83	0·98
			6·75	7·48	0·84	0·99
SP	9·32	0·61	9·14	9·51	0·55	0·60
			8·56	9·87	0·53	0·61
			8·95	9·57	0·55	0·62
SP	10·62	0·32	10·24	10·92	0·32	0·35
			10·40	11·19	0·32	0·34
			10·27	11·21	0·33	0·35

As would be expected, if the ends be excluded, extruded rod is more homogeneous along its length than cast pencils. There were, however, marked differences in the aluminium and zinc contents between batches of extruded rod manufactured from billets cast consecutively from the same melt.

Attempts were made to improve the homogeneity of cast pencils by experimenting with various die coats, and with die and melt temperatures, but no significant improvement could be effected, particularly for aluminium. Pencils were subjected to radiographic examination in conjunction with sparking along their lengths. By this means it was found that some of the major variations of aluminium and zinc could be co-related with porosity, or blow-holes due to gas entrainment, and although this relationship was not constant, pencils absolutely free from these defects always showed a relatively low amount of scatter.

With both forms of discs, the reproducibility of results improved as the centre planes were approached. The figures in Table III are typical for vertically cast discs. Similarly, when sparking 0·25 mm. from either face of a horizontally cast disc, erratic high results were obtained for aluminium and zinc. These near-surface layers usually had aluminium and zinc contents 10–15% higher than the remainder of the disc. The central planes gave much more uniform results.

TABLE III.

Distance from Surface (mm.)	Reproducibility (per cent. standard deviation)	
	Aluminium%	Zinc%
0·6	3·33	3·15
1·2	2·87	2·44
1·8	2·26	1·91
2·5	2·08	1·85

Sparking on the central planes gave variations from disc to disc which were considerably less than from pencil to pencil.

Over the element ranges investigated it was noted that, in pencils, general heterogeneity of aluminium and zinc was most likely to occur in the range 8·4–9·3% aluminium. It also appeared that the zinc variation was more serious in the absence of copper.

Much attention has been paid to longitudinal segregation, but transverse segregation can also occur in pencils, affecting the outside surface in particular. Because of this, and other reasons, it has long been our standard practice to turn down from 6 mm. to 3 mm. diameter, to get the most reproducible results.

Conclusions

From the foregoing work it may be concluded that the use of cast pencils for accurate control spectrographic analysis of aluminium in magnesium alloys is impractical. Reasonable results for zinc and other elements can be obtained provided there is adequate control of the samples.

To effect a general improvement in reproducibility and, in particular, to facilitate the routine control determination of aluminium in magnesium alloys, the homogeneity of pin samples must be greatly improved. This can be done, and then only inconsistently, by using the very best possible casting conditions. Having thus obtained

a suitable sample in which the pencil lengths have been carefully controlled, the sparking zone must be carefully selected, and multiple sparkings (e.g., six) must be used. These conditions do not lend themselves to easy routine operation. *Small diameter extruded rod does not appear to be a suitable alternative to cast pencils.*

With cast discs, particularly the horizontally cast type, variation through the thickness is less pronounced than along the length of a pencil, and machining is much simpler. Furthermore, it is felt that further improvement could be effected by the use of a higher powered, polarized source unit, e.g., the Walsh G.P. unit, and by paying more attention to the counter electrode geometry. *The horizontally cast disc form probably offers the simplest alternative sample form to the cast pencil, and merits further investigation.*

Acknowledgment

The authors wish to thank Dr. W. M. Doyle, F.I.M. and Mr. H. Proffitt, A.I.M., for their help in this investigation, and the Directors of High Duty Alloys, Ltd., for permission to publish this article.

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A Note on the Control of Light Emission in the Spectrographic Analysis of Aluminium Alloys

By E. C. Mills, F.R.I.C. and S. E. Hermon

Research and Development Division—High Duty Alloys, Ltd., Slough

As part of a general programme on the reproducibility of spectrographic analysis of aluminium alloys, errors contributed by the photographic plate, the source units and the sample form have been investigated, some aspects of which have been reported in this journal.[1,2]

Throughout this work, the exposure period was controlled automatically on a time basis (i.e., the normal spectrographic procedure). We have always noticed however, that the reproducibility of a batch of samples is often lowered by the presence of one or two spectra with very different overall densities from the majority. This occurred with various source units, even when they were strictly monitored, thus appearing to rule out the excitation conditions as the main cause.

Thought was given to the idea of controlling the total amount of light emitted from the discharge, as a possible means of controlling reproducibility. A simple unit for light control was constructed, incorporating a Mullard 90 AV vacuum photocell, and light from the analytical gap was focused on to it by means of a quartz lens. The output from the photocell was allowed to charge a selected condenser, which when charged, operated an electronic relay connected to the source unit and shutter.

Reproducibility tests were carried out with and without the unit in operation, and using pin samples of a general purpose, spectrographic alloy (copper 2·29%, nickel 1·08%, iron 1·09%, magnesium 1·52%, silicon 0·81%, titanium 0·06% and manganese 0·036%). Three different spark sources were employed, which were not monitored, and in which the selection of the best operating conditions was deliberately avoided.

TABLE I.

Source unit	Timing Method	Reproducibility of Aluminium Line Readings	Overall Element Reproducibilities
Hilger	Time control	4·71	2·95
	Light control	2·19	2·24
Feussner	Time control	7·65	3·35
	Light control	3·64	2·43
Walsh	Time control	10·31	6·83
	Light control	5·88	6·12

* With correct running and monitoring of the Walsh unit, the aluminium line density and the overall element reproducibilities were brought to the same general level as the Hilger and Feussner units, but the results for the time control and light control showed the same difference.

The reproducibility of the aluminium line readings and the overall reproducibility for the alloying elements were calculated for each spark source. The average results are given in Table I, which is based on results from a number of plates.

Conclusions

It is seen from Table I that controlling by light emission improved the reproducibility of the aluminium line densities by about 50%, resulting in an improvement of only 0·8, or 10–20% in the element reproducibilities. Although the erratic spectra were removed, the element reproducibility was not improved to the extent expected, thus lending further support to the theory that the sample contributes the most to the errors obtained in spectrographic analysis.

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Non-Destructive Testing Society

The Society of Industrial Radiology and Allied Methods of Non-Destructive Testing commenced its winter programme during October. This Society, which was founded at the close of last year, and now has a membership of over 200, is the first professional body, in this country, endeavouring to co-ordinate all specialists employed in the various methods of non-destructive testing. Its chief concern is to establish and maintain a high standard of technical practice and to facilitate the exchange of information and ideas on matters concerning these rapidly expanding methods of inspection. With these objects in view a programme of monthly meetings has been arranged by the branches of the Society at London, Birmingham, Sheffield and Glasgow. Particulars of the Society's activities are obtainable from the Honorary Secretary, Mr. D. N. Laurie, 2, Tomswood Terrace, Barkingside, Essex.

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